Innovation and Stagnation

In Automotive Safety and Fuel Efficiency

By Rob Cirincione

Preface by Ralph Nader

Center for the Study of Responsive Law Washington, DC

About the Author

Rob Cirincione, researcher, Center for the Study of Responsive Law
B.S.E., Mechanical and Aerospace Engineering, Princeton University

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Preface by Ralph Nader

As was the case in the late nineteen sixties, it is long overdue for the American people to send a determined wake-up call to the domestic auto industry, now represented by General Motors, Ford Motor Company and DaimlerChrysler. Then, there were many automotive engineering advances long on the shelf kept out of vehicles where they could have saved lives, reduced toxic air pollution and increased fuel efficiency. Today, there is another generation of backlogged engineering advances well suited for commercial application and widespread diffusion. Today, as was the case 40 years ago, auto company top management stands in the way of this new age of benign and efficient automotive technology.

What has happened between the first generation of successful technology-applying regulations and the present generation of motor vehicles? With few exceptions, a vast wasteland of technological stagnation and junk engineering from domestic automakers destroyed over three decades of opportunities for increasing the health, safety and economic efficiency of the motoring public. This "dark age" of the domestic motor vehicle industry was not the result of a series of omissions. It was the product of a deliberate expansion of the auto giants' power to block each and every stimulus, every prod and every dynamic process which would have jolted these behemoths out of their complacent, myopic stupor.

Consider the enormity of this prolonged executive obstinacy even against the necessities of their own commercial objectives, not to mention their responsibilities to minimize the damage from their products to people and society. During this period, the Big Three, with all their autocratic hierarchical bureaucracies, managed to continue losing market share to foreign manufacturers, now down to about 60% from the postwar time when they started at 100%. General Motors and Ford are experiencing massive annual losses, which would be even more immense absent their profitable financing arms. Their bonds have been downgraded to junk status—something unthinkable a decade or two ago. Their stock prices are near rock bottom with total valuations smaller than an upstart software or search-engine company. Their contract obligations with their workers are starting to shatter, undermining the stability of management-labor relations.

One might think that such a state of affairs would itself constitute an internal wake-up call to change directions and provide annual value improvements in their products on matters that count. No way. Notwithstanding advertising campaigns representing mere words, it is still business as usual. Still bringing up the rear guard behind foreign producers. Still tiptoeing toward securing indirect subsidies from Washington.

Unwilling over the years to regenerate themselves from within their ranks, despite substantial investment, marketing and engineering/scientific resources, top executives managed to mismanage and waste these estimable assets, reserving their energies to blockade external pressures that would have saved them from themselves, from their own ineptitude.

In a systematic campaign utilizing their varieties of political power, the auto manufacturers, together with their dealers and sometimes the United Auto Workers, froze regulatory activity in both NHTSA and EPA into obsolescence and even on occasion rolled back simple standards (such as bumper protections requirements) as if to rub in their supremacy over Washington, D.C. Auto management worked overtime to support legislators and candidates for Congress and the White House who pledged to take the federal cop off the corporate beat. These corporate bosses refused to recognize that up-to-date regulations could enhance their competitive position *vis-à-vis* their European, Japanese and Korean competitors. Domestic companies would have fallen further behind their foreign counterparts on fuel efficiency if the 1975 fuel efficiency law did not push them to modestly less gas guzzling models.

Not content with shutting down the regulatory prod to innovation, the auto executives also drove to eliminate competition, first through product fixing of their emissions systems and then through partnerships between Uncle Sam and the Big Three during the Clinton and Bush II Administrations. This strategy was a three-fer. It tapped into tax-payer money subsidizing alleged research for improved vehicles, legitimized collusion and avoided the antitrust laws banning such agreements, and replaced any regulatory moves with the argument that they were in partnership with the federal government. The result was to erect a barrier to competitive stimulation of innovation.

Their formidable lobby in Washington, replete with campaign funds, dealer political action committees and the powerful industry apologist, Democrat Congressman John Dingell strengthening their Republican allies, stopped any effort in Congress to recharge the General Services Administration into upgrading its safety, fuel and emissions specifications for its fleet purchases over the past twenty years. This occurred even though the GSA, under the leadership of Administrator Gerald Carmen, advanced air bag installations through fleet purchases in the mid-Eighties under Reagan.

Having nullified both the internal and external environments that would have pressed forward toward engineering excellence, the domestic Big Three reverted to their age-old profit formula. They jerry-built junk, profitable junk, called SUVs. The SUVs, as prize-winning New York Times auto reporter, Keith Bradsher, described in his book, *High and Mighty*, exacerbated the worst of Detroit engineering, turning the clock back on safety, fuel efficiency and emissions. They sold a mirage of safety, the status of size and huge horsepower and less cramped interiors. They invested tens of billions of dollars into more powerful and wasteful engines. They made up for declining market share with higher profit margins on vehicles sold. SUVs were the opiate of the auto executives, making them more complacent and sluggish during a lengthy period of stable gasoline prices.

Now the price of oil and gasoline is rising and the motorists may be awakening. So too should shareholders awaken. So too should the UAW awaken and drop its self-damaging support for auto management's opposition to higher CAFE standards. So too should the insurance industry and the engineering profession awaken to their loss prevention missions. So too should motorists raise their expectations for the kinds of vehicles they should be able to purchase in their own multiple interests. So too should political candidates and incumbents make the state of motor vehicle engineering a major political issue, extending to health, safety, efficiency and beyond to global warming, the lack of modern mass transit and geopolitical entanglements abroad.

This report—*Innovation and Stagnation in Automotive Safety and Fuel Efficiency* by Princeton-trained engineer, Rob Cirincione, makes the detailed case for raising public expectations and demands upon the auto industry. The backlog of engineering improvements is immense. Automotive suppliers have innovated while the auto makers have obstructed widespread commercial application of their innovations. So too have solid inventors and university-based researchers contributed materially. Important, feasible engineering innovations are ready to diminish serious national transportation problems.

Our government has the authority and the tools to move their applications into the assembly lines and the dealer showrooms. The engineers and scientists inside the auto companies are ready to work at higher levels of significance. There are serious roadway, environmental, economic and global urgencies at stake. We all have a role in confronting the executive mastodons of the auto industry who are stuck in their own traffic. It is time to put the federal cop back on the auto companies' beat. Get rid of the backlog. Put the benefits in the hands of the motorists. And, save the domestic auto companies from their own witless masochism.

Rob Cirincione's report is blowing the whistle to help get the traffic moving again through enlightened public policy, motorist demand and progressive engineering. Over thirty years of stagnation are quite enough. An entire new corps of the top executives is needed to provide a leadership of receptivity to, if not of outright initiation toward a new generation of motor vehicles.

February 2006

Executive Summary

On August 10, 2005, President George W. Bush signed into law the Safe, Accountable, Flexible, Efficient, Transportation Equity Act: A Legacy for Users (SAFETEA-LU). The Act authorizes federal surface transportation programs for 2005-2009 and includes key safety provisions directing the National Highway Traffic Safety Administration (NHTSA) to study or issue rules pertaining to rollover prevention, occupant ejection, roof strength, side-impact crash protection, tire aging, vehicle backover avoidance, non-traffic incident data collection, and power window switch safety.[1]

Many of the solutions relevant to such safety considerations lie in advanced life-saving technology. Similarly, NHTSA's responsibility to set fuel economy standards is heavily influenced by the industry's technological potential and its technological response to regulation. On August 30, 2005, NHTSA issued a Notice of Proposed Rulemaking (NPRM) that revises the procedures used to determine manufacturers' compliance with corporate average fuel economy (CAFE) standards.[2] The revised CAFE rules propose separating light trucks[3] into size classes.

As NHTSA complies with the SAFETEA-LU Act and considers comments on the reformed CAFE proposal, it is useful to characterize the general behavior of the automotive sector with regard to technological innovation and evaluate the impediments to novel product development and subsequent market diffusion. For the purposes of this report, technological innovation is defined as the first commercially feasible application

[1] SAFETEA-LU, Public Law 109-59, 2005
[2] Average Fuel Economy Standards for Light Trucks; Model Years 2008-2011, NPRM, NHTSA 2005-22223
[3] Light trucks are pickups, SUVs, and certain minivans.

of a new technical idea. Innovation is distinguished from invention, the first development of a technical idea—and diffusion, the market dissemination of an innovation.

Insofar as innovation can offer benefits to consumers and competitive advantages to producers, conditions that encourage innovation are universally favorable. This report evaluates the automotive industry and the many actors therein, in order to characterize consumer need, technological potential, and the necessary enablers to promote innovative automotive solutions to problems of safety and fuel efficiency.

While this report highlights many promising endeavors, persistent and institutional barriers exist within the automotive industry that delay the arrival of valuable technology. A summary of these obstacles is presented below.

- **The manufacturer-supplier relationship is not conducive to innovation**

  Within the automotive sector, parts suppliers develop innovative technology most readily and frequently (although independent and university inventors make important contributions). Automakers, however, have demonstrated an historical reluctance to incorporate the most advanced designs available, and have generally debuted substantial product improvements only in low-volume niche models. Without the supportive collaboration of vehicle manufacturers, new technology will never arrive in the marketplace, stifling innovation. Suppliers cannot bypass vehicle manufacturers to market directly to consumers, and so without demand or interest from automakers, technology will languish.

  Yet the Detroit automakers have generally preferred cheap parts to innovative parts. The business relationship between domestic motor vehicle manufacturers and their suppliers is dominated by cost demands as opposed to innovative product development. Some automakers have even shared suppliers' innovations with competing parts makers, eroding trust. Many suppliers are now financially unable or strategically unwilling to approach major automakers with innovative technology.

  These effects are compounded by the oligopolistic nature of the automobile industry, which discourages market-disturbing innovation.

- **Government research priorities are misplaced**

  Federally funded research for motor vehicle safety and fuel efficiency is misdirected. Major initiatives in fuel efficiency, like the Partnership for a New Generation of Vehicles and FreedomCAR, overlook near-term solutions, authorize collusion between large automakers, protect the anti-innovative nature of the auto industry, and ignore its most innovative segments. More than $1.5 billion has been spent on these collaborative programs, but no revolutionary advances have been achieved. On the other hand, the 1970's-era Research Safety Vehicle (RSV) program—contracted by NHTSA to small automotive firms—delivered marketable, affordable, production-capable vehicles that achieved revolutionary levels of safety and fuel economy with a modest budget. By 1980, the RSV program contracted to Minicars, Inc. had spent just $36 million (adjusted for inflation) and had constructed 18 prototype vehicles capable of achieving 31 mpg and protecting occupants in 50 mph crashes.[4]

- **NHTSA is not attentive to innovators at the early development stage**

  Without ongoing programs like the RSV, NHTSA does a poor job of monitoring the progress of automotive parts suppliers and independent inventors, who forecast the direction of automotive technology. Although such innovators rely on confidentiality to ensure competitive advantage and patentability, NHTSA has tools (such as the formal information request) that balance the privacy needs of entrepreneurship with the informational needs of a government agency charged with staying abreast of the most technically viable solutions to motor vehicle safety.

  When NHTSA sends information requests to officially gauge technological progress in the industry, however, it concentrates exclusively on large OEMs.[5] NHTSA becomes aware of novel initiatives by smaller actors in automotive technology usually only after the results are commercially apparent or reported in research literature.

- **NHTSA is slow to evaluate the effectiveness of emerging technology**

  Once innovative technology is reported, NHTSA is slow to evaluate its effectiveness. Data collection techniques like statistical sampling through the National Automotive Sampling System (NASS) are not ideally suited to the assessment of emerging safety technology. These samples investigate only a small fraction of motor vehicle crashes, limiting the

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[4] *The Safe, Fuel-Efficient Car: a report on its producibility and marketing*, NHTSA, December 1980

[5] Original equipment manufacturer. In the automotive sector (and this report), the term OEM refers to vehicle manufacturers.

chances that the randomly selected crash events will include vehicles equipped with innovative features. Sampling is a suitable tool to detect crash trends over time, but is a poor substitute for evaluating new technology in field trials. A better method for evaluating innovative vehicle technology would involve closely monitoring the on-road performance of experimental fleets.

In addition, statistical and competent analyses of expected safety benefits of new technology (e.g., ejection prevention if laminated glass were to replace tempered glass in side windows) could be applied more extensively by the agency.

- **NHTSA is not prepared to evaluate integrated technology**

Motor vehicle crashes are dynamic events that involve multiple vehicle systems. The most effective response is an integrated and dynamic system as well. Automakers can design safety systems that integrate functions—even connect crashworthiness and crash avoidance—but NHTSA has few tests to evaluate them.

During a rollover, for example, seat belt performance is dependent on vehicle body integrity (seat belt mounts may be forced out of position if the frame deforms). However, NHTSA's roof crush standard—designed to simulate a rollover—only considers the deformation of the roof, and is too weak at that.

Standards that replicate dynamic events will encourage the production of more advanced technology, which the industry is already capable of offering.

- **NHTSA does not act in a technology-forcing capacity**

There is no record of NHTSA ever imposing a safety standard or fuel economy standard which forced manufacturers to develop innovative technology, even though it has the ability to do so. NHTSA's regulations only schedule the deployment of existing technology. By contrast, studies have shown that other federal agencies responsible for setting environmental and safety standards, like the Environmental Protection Agency and Occupational Health and Safety Administration, have sometimes acted in a regulatory capacity that spurred radical industry response.[6]

[6] *Using regulation to change the market for innovation*, Ashford, N., Ayers, C., Stone, R., Harvard Environmental Law Review, Vol. 9, No. 2, 1985

NHTSA has also refused to update obsolete standards, including the seat belt standard and the roof crush standard—which was proposed to be revised 34 years after it was first issued. The agency has studied safety concerns outside the scope of current standards, like pedestrian protection and visibility, but has not acted.

- **Automotive engineers do not practice as professionals**

The automotive engineering community has never established licensure requirements, binding codes of ethics, or protocols of personal accountability that would elevate the practice from an employed vocation to a more independent self-governing profession. In the absence of an expressed duty to safeguard the public welfare (as Profession Engineers, P.E.'s, are sworn), a critical internal stimulus that might spark greater technological advances in safety and fuel efficiency is notably missing from today's automotive engineering circles. The importance of such an advisement derives from the hybrid nature of the job, as science and business exert often conflicting pressures on automotive engineers—who work in both worlds and yet not completely in either.

- **Insurers refuse to offer incentives for safety**

Automobile insurers offered premium discounts for cars purchased with frontal airbags before they were standard, but have not done anything similar since. During the 1990's, insurers actively covered up higher liabilities of SUVs by averaging casualty costs across model lines.

Further, auto insurance policies do not cover the true cost of motor vehicle crashes, hindering the ability of insurance premiums to convey the full damage potential of motor vehicle operation and likewise stimulate the purchase of less dangerous models. While auto insurance payments for liability claims or medical bills are usually capped at $100,000 or $300,000, NHTSA estimates that the economic cost of a severe injury suffered in a motor vehicle crash is more than $1 million. Because auto insurers are not financially responsible for the total damage caused by motor vehicle crashes, insurance premiums only cover limited losses and therefore do not fully reflect driving risks. Accordingly, premium prices and premium price differences between models are not proportional to the relative factor of safety of particular vehicles.

- **Options bundling and pricing reduces demand for safety features**

Vehicle manufacturers often dissuade buyers from choosing life-saving technology by packaging it with other features in expensive bundles. For example, electronic stability control costs manufacturers about $100 to install, but options that include electronic stability control (ESC) can exceed five times that amount. If ESC were standard on all cars, the incremental cost to manufacture would drop even further.

- **Consumers lack information to make the most educated decisions**

  Passenger vehicle technology is more sophisticated than ever. An information asymmetry arises between automotive experts (the automakers and their engineers) and novices (most car buyers) in the marketplace which limits the ability of consumers to make the wisest decisions. Certain safety considerations, like roof crush resistance, are all but hidden from the consumer. When rules like NHTSA's roof crush standard establish a low level of safety, it can be extraordinarily difficult for the buying public to discern higher degrees of protection that certain models may offer.

  Crash tests and consumer information programs, like NHTSA's New Car Assessment Program (NCAP), and independent studies performed by the Insurance Institute for Highway Safety (IIHS) offer important data, but do not evaluate every critical component of vehicle safety. Neither NHTSA nor IIHS perform roof crush resistance tests.

Identifying these innovation impediments and contrasting them to *best practices* is exceptionally urgent, as critical metrics of passenger vehicle performance—including average fleet fuel economy and annual traffic fatalities—remain unchanged or have regressed in recent years. Today, the average fuel economy of the domestic fleet is at a 25-year low, and motor vehicle crashes are the leading cause of death for persons age three to 33. Moreover, NHTSA's ability to attend to these problems creatively and effectively is essential, considering that the agency's chronically underfunded and understaffed existence leaves no room for waste or diversions. With a mere one percent of total Department of Transportation resources, NHTSA cannot afford to stumble.

Nor can the safety agency be swayed by invalid arguments against progressive standards that ignore the true technological potential of modern engineering. Ideological opponents of basic fuel economy standards, for example, continue to level an outdated claim—arrived at by a divided research panel—which asserts that raising fuel economy standards (known as CAFE) encourages the production of passenger vehicles that are less crashworthy. Yet a review of the most recent studies, expert opinions, and congressional testimony on this issue disputes the notion that fuel economy standards have made vehicles less safe and shows that any fuel economy/crashworthiness tradeoff can be easily obviated by means of current technology. In February 2005, for instance, five members of a panel appearing before the House Committee on Science—including a top EPA official under President George H. W. Bush, a representative for the auto industry, and members of the National Academy of Sciences—all agreed that fuel economy standards could be increased without making vehicles less safe. Panel members refuted the notion that setting fuel economy standards ever caused increased traffic fatalities and cited the adoption of technology as one means to lower fuel consumption without sacrificing safety.[7]

Industry arguments against improved safety standards make comparable mistakes and frequently underestimate the creativity of the talented automotive engineering corps. In one glaring example, Ford Motor Company has challenged the need or practicality of strong roof crush standards; even though Volvo (owned by Ford) builds an SUV with a roof strong enough to withstand a rollover without suffering visible deformation. Thus instead of attempting to exceed NHTSA's safety standards to their competitive

[7] "Experts: Technology exists to raise fuel economy of cars and trucks without reducing safety," news release, House Committee on Science, February 9, 2005

advantage, developing solutions that leap vehicle technology beyond these minimum requirements, most major manufacturers fight new proposals and shrink from the opportunity to innovate.

Automakers also push for the lowest common denominator of vehicle safety at the international level, where global safety standards are negotiated in a complicated process called harmonization. Harmonized standards, applicable to vehicle makers around the world, will raise the degree of vehicle safety in developing nations where no standard previously existed, but could very well amount to stagnant and weak rules domestically. The massive inertia of the harmonization proceedings causes longtime safety advocates to worry that the probability of revising newly-harmonized standards in the near term could be almost zero.[8] One exception to the harmonization pitfall is the rare case where NHTSA lags foreign safety standards, as it does with pedestrian safety. A pedestrian safety standard has already been enacted in Europe, and would be extremely beneficial in the US, where 11 percent of all traffic fatalities are pedestrians and no pedestrian standard exists.[9]

Notwithstanding NHTSA's role as a standards-setter, the agency could issue various challenges to industry, entrepreneurs, inventors, and students that seek innovative vehicle solutions to safety and fuel economy problems through a contest format. Agency funding and oversight of such a contest could range from minimal to moderate, be either systems-based or vehicle based, and could build on the research success of other vehicle contests like the Department of Energy's FutureTruck and the Department of Defense's Grand Challenge. Such a contest would complement NHTSA's formal research, augment

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[8] "US agrees to door-latch standard," Dee-Ann Durbin, *Associated Press,* November 16, 2004
[9] *Traffic Safety Facts: 2004 Data*, DOT HS 809 911

the agency's knowledge base, and might inspire more engineers to pursue vehicle safety research.

Broadly, the conclusions and recommendations presented here—whether they apply to the withered National Highway Traffic Safety Administration, the inert General Services Administration procurement process, the inflexible domestic auto industry, the unassertive automotive engineers, or various other stakeholders—provide a comprehensive review of proven strategies that could reinvigorate motor vehicle product development and support the commercial production of more sustainable passenger vehicle technology.

Conclusions and Recommendations

1. **Government-funded research in fuel efficiency and vehicle safety should follow successful contracting patterns like the Research Safety Vehicle program and the Small Business Innovation Research program, not billion-dollar boondoggle partnerships with industry.** Promising long-range research from the FreedomCAR program should continue in federal labs, but without industry involvement. NHTSA's overall budget, including research and development, should be doubled.

2. **The General Services Administration should leverage its large procurement program to stimulate the purchase of life-saving and fuel-saving innovations in the automotive sector.** Tracking the on-road performance of fleet vehicles equipped with emerging safety technology and advanced monitoring devices like electronic data recorders will foster better data collection and a swifter evaluation of innovative technology than the current statistical sampling plans that NHTSA employs. The resultant data from these make-shift field trials can be used by NHTSA to evaluate the benefits of particular technologies and their pertinence to ongoing rulemakings.

3. **NHTSA must issue a pedestrian safety standard and a visibility standard, both long overdue and easily written considering auto manufacturer's technological capability in each area.** Obsolete standards which have not been significantly overhauled in years, including those relating to seat belts, must be updated.

4. **The National Highway Traffic Safety Administration must collaborate with small parts suppliers and entrepreneurs.** As NHTSA fulfills its statutory obligations under SAFETEA-LU, it should proactively send parts suppliers and entrepreneurs information requests in order to gain an accurate assessment of the most advanced vehicle safety technologies available, and those technologies which have yet to appear commercially but are under investigation.

5. **NHTSA should add an additional component to its New Car Assessment Program (NCAP) to test and recommend active safety technology like electronic stability control**. Integration of active and passive safety features will provide greater overall vehicle safety.

6. **Trends within the auto insurance industry to adjust premiums by model should continue.** More advanced risk assessment and policy variation must be encouraged, and the viability of insurance plans that cover the complete economic

costs of motor vehicle crashes should be investigated. The auto insurance industry itself should attempt to offer incentives for emerging safety technology.

7. **The Society of Automotive Engineers should adopt a written code of ethics which stresses the interrelation of automotive engineering, ethical decision making, and the public welfare.** This is the first step toward establishing a community of automotive engineers who practice with degrees of independence and professionalism commensurate with their duty.

8. **Harmonization must be monitored closely by safety advocates both substantively and procedurally.** Global technical regulations may raise safety standards in developing nations, but they should never lower safety standards for the domestic fleet.

9. **Fuel economy standards (CAFE) can be raised significantly for both cars and trucks by means of current technology, without safety risks.** CAFE should be raised to 46 mpg for cars and 40 mpg for light trucks by 2014, as has been shown technologically feasible by a 2001 American Council for an Energy-Efficient Economy study.

10. **NHTSA should design a super-efficient and extra-safe vehicle contest, similar in scope to the Department of Energy's FutureTruck or the Department of Defense's Grand Challenge.** In 2005, a privately-funded team successfully won a $10 million prize for piloting a manned flight to the threshold of space. NHTSA should challenge inventors and entrepreneurs to deliver a similarly noteworthy sustainable motor vehicle.

1. Personal and Environmental Consequences of Motor Vehicle Design

Fatalities due to motor vehicle crashes are the leading cause of death in America for ages three through 33.[10] According to the Department of Transportation, 42,636 people died in automobile accidents in 2004.[11] In other words, every year the United States suffers a highway casualty count equal to 365 airplane crashes—or more than fourteen September 11 attacks.

The societal costs of such injury, death and destruction are immense. The Department of Transportation estimated the annual economic cost of motor vehicle crashes at $230 billion in 2000, or $7,300 *per second*.[12] Moreover, these figures do not capture the emotional and psychological toll caused by the death, disability, and duress associated with motor vehicle trauma.

Automotive safety is a national crisis and public health emergency.

Of equal concern is the deplorable fuel economy of the American fleet, which has been dubbed an environmental calamity and national security risk.[13] The United States, given its limited fuel production capacity, is increasingly forced to rely on imported oil to satisfy its energy needs. As a result, American dependence on imported oil has risen

[10] *Traffic Safety Facts: Research Note*, January 2005, DOT HS 809 831
[11] *Traffic Safety Facts: 2004 Data*, DOT HS 809 911
[12] Ibid
[13] *Ending the Energy Stalemate: A Bipartisan Strategy to Meet America's Energy Challenges*, National Commission on Energy Policy, December 2004. Opening statement for CAFE hearing, Congressman Sherwood Boehlert (R-NY), February 9, 2005, before House Science Committee. *Clean Vehicles, Backgrounder: Energy and Security,* Union of Concerned Scientists, http://www.ucsusa.org/clean_vehicles/cars_and_suvs/page.cfm?pageID=225

from 8% in 1949 to 63% in 2003.[14] One-fifth of our imported petroleum arrives from the Persian Gulf region,[15] heightening the risk of market instability and political tumult.

Motor vehicles are literally driving this demand, accounting for 44% of all domestic petroleum consumption, more than any other machine, process or industry.[16] Every year Americans drive farther and consume more fuel, in no small part because they are driving inefficient vehicles—those that are inherently wasteful fuel users (large and heavy trucks) and those that are engineered for maximum acceleration (high horsepower vehicles). The combined fuel economy of new cars and trucks is hovering at 1981 levels,[17] depressed by engine technology that has improved horsepower over fuel economy, the industry flood of gas guzzling SUV's and their preferential treatment under law, and the woefully inadequate corporate average fuel economy (CAFE) standards—not changed for cars since the 1975 CAFE law was passed.

It is clear that automobiles cannot continue to run on natural gasoline supplies forever. Princeton University Professor Emeritus Kenneth Deffeyes predicted that world oil production would reach a peak sometime before Thanksgiving day, 2005, and would decrease from that point forward.[18] As oil production declines, costs will rise.

Experts who disagree with Deffeyes's conclusion do not offer attractive alternatives, including the extraction of oil from tar sands (a process that relies heavily on natural gas consumption), and the promotion of Fischer-Tropsch type coal to oil

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[14] [crude oil imports/crude oil production] US Energy Information Agency, Annual Energy Review 2003. http://www.eia.doe.gov/emeu/aer/petro.html
[15] Energy Information Agency, Annual Energy Review 2003. http://www.eia.doe.gov/emeu/aer/petro.html
[16] U.S. Energy Information Agency, International Petroleum Information, World Oil Demand 2000-2004, http://www.eia.doe.gov/emeu/international/petroleu.html
[17] *Light Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005*, EPA, Office of Transportation and Air Quality
[18] "It's the end of oil," Kenneth Deffeyes, *Time*, October 31, 2005

conversion,[19] which requires huge primary energy inputs and yields higher carbon emissions than conventional petroleum use.[20] Neither prospect is appealing.

In addition to concerns of consumption and dependence, the fuel economy of cars and trucks is related to global warming because greenhouse gases (GHG) are a byproduct of fossil fuel combustion. The internal combustion engine simply burns fuel with air and expels the resulting gas. For every gallon (weighing 5.9 pounds) of gasoline burned in a combustion engine, approximately 5.3 pounds of carbon in the gasoline combine with 14.2 pounds of oxygen in the air to form 19.5 lbs of carbon dioxide gas released through the tailpipe.[21] Carbon dioxide lingers in the upper atmosphere, where, along with water vapor and similar gases, it absorbs infrared radiation given off by the earth's surface. The carbon dioxide in turn re-radiates this energy in all directions, including back down to the lower atmosphere and the earth's surface. This results in the greenhouse effect, which has existed naturally on Earth and is necessary to sustain life. However, the release of *man-made* greenhouse gasses (like carbon dioxide) increases the concentration of GHGs in the atmosphere, amplifying the greenhouse effect and accelerating global warming.[22]

According to the EPA, fossil fuel combustion, like that from an internal combustion engine, accounts for approximately 80% of all greenhouse gas emissions in

[19] "Oil is here to stay," Peter Huber, *Time*, October 31, 2005
[20] *Life-Cycle Greenhouse-Gas Emissions Inventory For Fischer-Tropsch Fuels*, Marano, J., Ciferno, J., US Department of Energy National Energy Technology Laboratory*,* 2001
[21] Gasoline is comprised of many compounds, but primarily contains various forms of carbon. Other elements, like sulfur, combine with oxygen in air to form smog-causing pollutants.
[22] Global warming – climate, EPA, http://yosemite.epa.gov/oar/globalwarming.nsf/content/climate.html

the US.[23] Though the exact magnitude and consequences of the global warming process are in dispute, its existence, causes and potential dangers are irrefutable.

In sum, the inefficiencies of motor vehicles sold in the US portend undesirable political, economic and ecological outcomes of the most serious order and elevate the problem to a front rank national priority. Considered in tandem with the epidemic of motor vehicle injuries and fatalities, solutions to mitigate direct and indirect effects of automobile design are paramount.

[23] *The US greenhouse gas inventory*, EPA, 2005

2. Sustainable Passenger Vehicle Design and Innovative Potential

The quality of a passenger vehicle design can be evaluated by parameters of performance, reliability, efficiency, economy and safety. Environmental consequences of manufacturing[24] and operating the vehicle should also be considered.

Personal injuries and environmental degradation are indicative of particular failures in the road-vehicle-driver transportation system. Successful passenger vehicle and road system design therefore minimizes adverse effects on safety and the environment and maximizes efficiency, reliability and economy. A judicious application of engineering ingenuity presents the best solution currently practical. While the costs of technological progress can never be eradicated, the trajectory of industry can be aligned in a way that values sustainability and social responsibility.

With every creative advance in science and technology, the opportunity for an innovative solution to problems of auto safety and fuel efficiency arises. Profiling the existence and adoption of innovations related to safety and efficiency provides a fairly easy measure of the automotive industry's drive to achieve a sustainable solution. This report evaluates stakeholders within the auto industry and considers their contribution to the promotion and advancement of innovations in key areas of safety and efficiency.

[24] The Minnesota office of Environmental Assistance has reported on the sustainability of automotive manufacturing in its study *Product Stewardship Opportunities within the Automotive Industry*, August 2003

3. Responsibility, Ethics, and the Engineers' Role

Unlike dentists, hairdressers, and plumbers, automotive engineers are not personally responsible for their work product. Neither professional licensure nor enforceable standards of practice bind the automakers' engineering ranks. Even the relevant professional association, the Society of Automotive Engineers (SAE), lacks a code of ethics.

The absence of an ethical code distinguishes SAE among professional societies, which advocate ethical practice as a coordinated convention that encourages cooperation and good conduct among the membership.[25] Professional societies thus recognize best practices and issue codes of ethics. Yet the SAE abstains from ethical discourse, reflecting the automotive engineer's function as only quasi-professional. In practice, an engineer is a skilled specialist and a company employee, dual roles that confuse the formulation of ethical guidelines. Engineers who are responsible to their profession and their employer face competing pressures, described by University of Minnesota Mechanical Engineering Professor Edwin Layton in his seminal work *The Revolt of the Engineers*. "Engineering is a scientific profession," writes Layton, "yet the test of the engineer's work lies not in the laboratory, but in the marketplace. The claims of science and business have pulled the engineer, at times, in opposing directions."[26]

These antagonistic tendencies cleave a patchwork of professional engineering standards and spark ethical debates within individual engineering communities. For instance, though the SAE has no code of ethics, the American Society of Civil Engineers

[25] *Thinking like an engineer: the place of a code of ethics in the practice of a profession*, Davis, M., Center for the Study of Ethics in the Professions, Illinois Institute of Technology, 1991

[26] *The Revolt of the Engineers*, Edwin Layton, Johns Hopkins University Press, 1971, p. 1

(ASCE), the American Society of Mechanical Engineers (ASME), and the Institute of Electrical and Electronics Engineers (IEEE) all have professional ethical codes. But Joseph Herkert, Professor of Science, Technology, and Society at North Carolina State University, observes that discipline-based professional societies, even those with codes of ethics, have "in recent years for the most part only been giving lip service to the importance of engineering ethics."[27] Herkert notes that ASCE adopted a "limited notion" of sustainability in its newest code, ASME incorporated environmental protection in its code after "months of stonewalling," and IEEE suspended an ethics hotline after less than one year of operation.[28]

The forces that resist a broader involvement in engineering ethics typically represent the commercial side of engineering, where "engineers who hope to advance in the corporate hierarchy are expected to embrace business values."[29] The tension between engineering and business, says Herkert, "is exacerbated when the career paths of engineers lead to management positions."[30] Layton views the conventional career ladder of technical firms in even more destructive terms. "Insofar as business treats engineering merely as a stepping stone to management, it represents a denial of much that professions stand for."[31]

Historically, the conservative technological tradition of automotive engineering befitted the rigidly hierarchical corporate structure of automobile manufacturers and

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[27] *ABET's engineering criteria 2000 and engineering ethics: where do we go from here?*, Herkert, J., presented at the OEC International Conference on Ethics in Engineering and Computer Science, March 1999
[28] Ibid
[29] *Microethics, macroethics, and professional engineering societies*, Herkert, J., Emerging Technologies and Ethical Issues in Engineering: Papers from a Workshop, October 14-15, 2003, National Academy of Sciences, 2004
[30] Ibid
[31] *The Revolt of the Engineers*, Edwin Layton, Johns Hopkins University Press, 1971, p. 9

spawned an industrial culture more favorable to business concerns than autonomous professionalism. Compared to the burgeoning radio and electronics industry at the turn of the century, automotive engineering was characterized by a "weaker contact with science and less esoteric knowledge."[32] Pioneering captains of the auto industry were "practical men like Ford and Kettering," rather than "scientists like Steinmetz and Pupin."[33] As such, the nascent atmosphere of the auto industry did not engender a body of self-aware and self-governing technologists. The Society of Automotive Engineers resolved early on that engineering qualifications would exclude some managers from membership in the society and were therefore unnecessary, a decision that converted the organization "into something approaching a trade association."[34]

The SAE has continued to function as a trade organization and has unceasingly resisted the adoption of a code of ethics. No external pressures have ever forced automakers to adopt professional standards or set employment criteria. To this day, it isn't even necessary to have earned an engineering degree to work as an automotive engineer.

By contrast, strict guidelines and methods of accountability govern the engineering of buildings, structures, and public works. Engineers who submit construction plans to public authorities must be certified Professional Engineers (P.E.), and all structural and mechanical plans for a project must bear a P.E.'s seal. The National Council of Examiners for Engineering and Surveying (NCEES) oversees the state boards that license Professional Engineers and declares in its Model Rules that "licensees, in the performance of their services for clients, employers, and customers,

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[32] Ibid, p. 42
[33] Ibid
[34] Ibid

shall be cognizant that their first and foremost responsibility is to the public welfare."[35] Engineers who are found to violate this dictum can be stripped of their professional license.

Whether the automotive industry would benefit from the enactment of P.E.-like requirements, or from the adoption of a professional code of ethics, or even from a greater emphasis on engineering ethics in education, is only a question of identifying effective strategies—there is no doubt that an injection of ethics would be valuable. The responsibilities of automotive engineers beg for an ethical imperative and a professional convention similar to the practice of sister disciplines, like civil engineering. The public welfare is equally dependent on the performance of bridges and roads as the vehicles that travel them.

In 1966, the same year that landmark motor vehicle safety legislation was enacted by Congress, Ralph Nader delivered an address to the Middle Atlantic Section meeting of the American Society for Engineering Education, exhorting the engineering profession to apply its talents toward the remediation of technology's costs—a pursuit that he noted can be "as impressive as the engineering achievement that developed the technology." In closing, Nader remarked to the society that, "It is the recognition of this gap between promise and performance that is producing the pressures which continue to mount on the engineering profession and demand that it assert itself toward its most magnificent aspirations—for so much of our future is in your trust." These comments echo the public's demand for safe and efficient motor vehicle engineering that has continued unabated ever since Nader revealed the issues to popular scrutiny.

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[35] Model Rules, National Council of Examiners for Engineering and Surveying, 240.15(A)(1), August 2005

Today, such themes are highly marketable. In a recent advertising campaign, Bill Ford Jr., Chairman and Chief Executive Officer of Ford Motor Company, announced that Ford is committing itself to innovation by highlighting Ford's plan to increase production of hybrid vehicles and work closely on safety with its Volvo division.[36] The efficiency and safety initiative is a clever advertising tack, instilling in consumers a notion of socially responsible engineering by Ford Motor Company. It might even imply a commitment to some measure of engineering ethics from the leader of the third-largest automaker, a non-engineer who earned degrees in history and business.

[36] "Innovation is our mission," www.ford.com/en/innovation

4. Innovation and the Manufacturer-Supplier Relationship

While the global vehicle market is more diversified than ever, major automakers prefer incremental improvements and cost savings to radical technological change, retarding the pace of innovation. Some analysts have suggested that the international debut of hybrid electric vehicles in 1995 was the most revolutionary automotive innovation since the automatic transmission, featured in a 1940 Oldsmobile.

Small upstarts and agile competitors introduce novel products or innovative technology when giant corporations are rigid—but this effect is less noticeable in the automotive sector. High barriers to entry limit the number of automobile manufacturers and constrict the flow of innovation from small suppliers (where many new technologies are developed) to finished vehicles. Vehicle manufacturers, not consumers, exercise initial demand for new products by contracting parts development with component suppliers. Automakers have exploited this position in recent decades to obtain lower prices from suppliers, either by directly requesting cost concessions or by exposing suppliers' proprietary technology to competing parts makers, thereby reducing the premium suppliers can command for innovative designs they develop ahead of others. While suppliers can leverage both cost savings and product innovations to increase the appeal of their business, major automakers overwhelmingly focus only on the price-lowering abilities of their supplier base, at times undermining the collaborative relationship that promotes innovation in the first place.

John De Lorean's memoir *On a Clear Day You Can See General Motors* recounts several of the abusive tactics General Motors perpetrated in its dealings with suppliers during the 1970's. De Lorean, an engineering executive with Chevrolet and Pontiac, paints an image of a strong-arm giant with a penchant for underhanded tactics and a congenital disrespect for independent suppliers. One representative anecdote relates the saga of the Holly Carburetor Company, which learned Chevrolet was having trouble designing carburetors for the new subcompact Vega. During Vega development, Chevrolet had discovered that their carburetors would not satisfy emission requirements and were therefore planning to add a $25 air pump to every engine in order to burn exhaust gases.[37] In response, Holly Carburetor Company designed an innovative carburetor that met emissions requirements without the pump, saving GM $3 million.[38] Holly did not patent the design, however, because of a gentlemen's agreement common within the industry—in return for the new design Holly would receive business supplying these carburetors to GM for the Vega.[39]

After GM's Rochester Products Division found out, however, it got "panicky" that it might lose all Vega work.[40] What did GM do? They appropriated Holly's design and gave it RPD.[41] De Lorean wrote a memo to his superior, conveying his profound disappointment. "In my opinion, this decision was shortsighted and is one of the main reasons that General Motors has not led in a significant technical innovation since the automatic transmission. … To my mind, a supplier who makes a significant contribution earns some business—to use our suppliers otherwise is immoral."[42]

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[37] *On a Clear Day You Can See General Motors*: *John Z. De Lorean's Look Inside the Automotive Giant,* J. Patrick Wright, Avon Books, 1979, p. 78
[38] Ibid
[39] Ibid
[40] Ibid, p. 79
[41] Ibid
[42] Ibid

In the end, De Lorean fought for and won Holly Carburetor Company a share of the Vega business (manufacturing the very carburetor they designed) but the culture that endorsed such behavior remained intact. Suppliers are treated no more fairly today. "It's shameless what some manufacturers want to force on suppliers via terms and conditions," says Wolfgang Vogel of ZF Friedrichshafen AG, maker of drivetrain and chassis technology.[43] A profile of modern reverse-engineering operations at GM featured in *Wired* magazine shows the automaker to be applying the surveillance technique to purchasing negotiations as earnestly as product research, with surgical precision. Once a competitor's vehicle is completely disassembled, says staff project engineer Craig Duncan, "we know the mass of the part, what the labor rate is, and what the shipping costs are, and we start adding up all the puzzle pieces. It's a scientific way of being much more aggressive with our suppliers to push the costs down."[44] Major automakers have so focused the supplier relationship on cost reduction over product improvement that industry analyst Eric Wallbank reports some suppliers have altogether stopped approaching manufacturers with innovations.[45]

Vehicle manufacturers and parts suppliers have endured a strained relationship from the start. When Henry Ford began mass-producing vehicles, he sold a stake of Ford Motor Company to Horace and John Dodge, who agreed to manufacture axle, transmission and engine components at their Detroit machine shop.[46] Friction soon developed between the ambitious Dodge suppliers who demanded higher dividends and

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[43] "Suppliers skeptical of Ford, VW plans," Bradford Wernle and Tony Lewin, *Automotive News*, December 19, 2005
[44] "The teardown artists," Carl Hoffman, *Wired*, February 2006
[45] "Suppliers skeptical of Ford, VW plans," Bradford Wernle and Tony Lewin, *Automotive News*, December 19, 2005
[46] "Make or buy parts? The strategy has shifted," Dale Jewett, *Automotive News*, June 16, 2003

Henry Ford who sought greater manufacturing control.[47] Ford's solution to his supply-chain imbroglio was the Rouge manufacturing complex, a sprawling 2,000 acre compound that could produce entire vehicles, sans suppliers.[48] The Rouge plant epitomized Henry Ford's concept of vertical integration and though he continued to rely on suppliers, he significantly undercut their ability to leverage component delivery for price control.

Ford and GM, which undertook a similarly large engineering operation, became gigantic companies by the 1950's, able to design—and build—an entire car. Rather than apply the aggregate talent of so many in-house engineers, though, the auto industry slogged through technological doldrums during the 50s, and 60s, ignoring advances in safety and efficiency for style and marketing ploys.

While GM and Ford's product offerings languished amidst the enormous bureaucracy, automotive suppliers established themselves as "focused and nimble and expert at creating innovative products," according to a history of the OEM-supplier relationship profiled by *Automotive News*.[49]

By the 1990s, GM and Ford acquiesced to the separation theory and spun off their supplier divisions. Ford still maintains a flexible manufacturing plant at Rouge, though the production method is an adaptation of Japanese manufacturing techniques and a tight supply chain, not Henry Ford's vertical integration.[50]

Yet the separation of GM and Ford's supplier divisions (known as Delphi and Visteon) did not foster innovation or profitability by itself. In fact, Delphi was driven to

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[47] Ibid
[48] Ibid
[49] "Make or buy parts? The strategy has shifted," Dale Jewett, *Automotive News*, June 16, 2003
[50] "Manufacturing: Rouge reborn," Richard Truett, *Automotive News*, June 16, 2003

bankruptcy in 2005, one of thirteen major auto suppliers to file for Chapter 11 protection in that year.[51] It is not as important for a supplier to be officially independent as it is for the supplier to be able to operate within a product development cycle that values research, dynamism, communication, and collaboration along the supply chain. The judges of the *Automotive News* PACE Awards for Innovation observe that, "Innovation is a critical ingredient in competitive success, but like success or profits, [it] is a consequence of contextual conditions and mastery of larger business processes."[52] Contextual conditions and large business processes beneficial to innovation begin with the major automakers, who dominate the automobile industry.

The anti-innovative automotive sector

A predilection for innovation runs counter to the natural behavior of the automotive sector, however, because of the major automakers' incentives to follow a conservative technological course. While domestic automakers have seen their market share erode in recent decades, three manufacturers (General Motors, Ford Motor Company, and Daimler-Chrysler) still account for 60 percent of car and light truck sales in the US.[53] A relatively large portion of the new vehicle market encourages these large firms (especially GM and Ford) to rely on their financing arms for significant revenue. Every year that GM and Ford sell millions of cars and trucks, they generate millions of potential customers for their lending operations, General Motors Acceptance Corporation (GMAC) and Ford Motor Credit Company (Ford Credit). Further, these financing

[51] Presentation of William G. Diehl, Principal, COO & Automotive Group Lead, BBK Ltd., Automotive News World Congress, Jan. 17, 2006
[52] "PACE: What we've learned so far," *Automotive News*, 2005
[53] U.S. light-vehicle sales by nameplate, December & 12 months 2005, *Automotive News*, January 9, 2006

operations have grown so expansive[54]and remained so decently profitable, that their success distracts from the failures of core automotive divisions. In the third quarter of 2005, for example, Ford suffered a staggering $1.3 billion pre-tax loss in its automotive business but enjoyed a $1.1 billion pre-tax profit in its financial services sector.[55] General Motors has tolerated a similar balance sheet for years. If the income from their financing divisions were ignored, a spotlight on Ford and GM's faltering automotive divisions would shine brighter—and motivate the companies to aggressively pursue product improvements and technological advantages.

Yet rather than compete with innovations in safety and efficiency to win back customers in the American marketplace, General Motors and Ford are turning their sights toward China. "We're very bullish," said Kevin Wale, president of GM China group, at an industry conference in Fall 2005.[56] In China, automakers eye the fastest growing and second-largest overall passenger vehicle market (after the US). According to the Associated Press, China car sales grew 27 percent from 2004 to 2005, to 3.2 million units.[57]   For comparison, eight million cars were sold in the US in 2005, but this represented a meager 3 percent increase from 2004.[58] This burgeoning Asian marketplace is diverse, with over a dozen automakers selling vehicles in China, and is dominated by General Motors[59]—though Ford is rapidly increasing sales and share.[60]

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[54] GMAC offers fixed rate investment notes, money market accounts, CD's, private education loans, home mortgages, home equity loans, real estate brokerage, homeowners insurance, RV insurance, motorcycle insurance, automobile insurance, and automobile loans. Ford Credit offers numerous investment opportunities, loans, financing, disability insurance, life insurance, and automobile insurance.
[55] Ford reports third quarter 2005 financial results, press release, Ford Motor Company, October 20, 2005
[56] "Auto exes optimistic about China market outlook," *Automotive News*, October 18, 2005
[57] "China car sales jump 27 percent in 2005," *Associated Press*, January 11, 2006
[58] US car and light truck sales, *Automotive News,* January 9, 2006
[59] "GM tops VW for China sales lead," *Automotive News*, August 15, 2005
[60] "Ford Motor sees record 2005 China vehicle sales," *Reuters*, January 16, 2006

Beleaguered automakers like GM and Ford are attracted to the young market in China by its wide profit margins and tremendous potential for expansion. In July 2005, Wale confirmed that, "China continues to be a very solid profit contributor" for GM, as the company made $417 million in China during the previous year.[61] Like SUV's of the 1990's; passenger vehicles sold today in China present a fairly easy and large profit for manufacturers. The Chinese government is only just starting to consider the benefits of US-style vehicle assessment programs, and so the near-term pressure on automakers selling in China to advance life-saving and fuel-saving innovations is markedly weak.

Even before major manufacturers unveil new models to customers, many squander the most innovative segments of the development cycle. Suppliers, for example, are withstanding an aggressive pursuit from automakers almost exclusively directed at lowering component prices and not toward product improvements. According to the Jan 9, 2006 *Automotive News*, consultant Ronald Berger and research firm SupplierBusiness.com surveyed 100 supplier executives and found that

- 70% predicted chapter 11 filings by Tier 1 suppliers will increase
- 43% expect relations with OEMs to get worse
- Executives fear their companies will not be compensated adequately for research and development
- Suppliers see price pressure from OEMs as the biggest challenge

[61] "GM sees record car sales in China," *BBC News*, July 6, 2005

- Suppliers are worried that the restructuring of the business brought about by globalization will force Tier 1 and Tier 2 sourcing to India, China, and eastern Europe[62]

These findings indicate that for the most part, automakers view parts suppliers in a narrow cost-cutting context and resist tapping their innovative potential. This attitude creates an environment adverse to innovative product development throughout the automotive design cycle.

Other factors that inhibit the innovation function stem simply from the market behavior of the automotive sector, in which the dominant firms are prone to interdependent decision making,[63] and high barriers (technical complexity, research and development costs) limit the entrance of new producers. Thus the established manufacturers vie for slivers of a mature market (or they engage an emerging market as in China) and the net effect is a focus on near-term profitability instead of revolutionary change. In 1978, MIT's Center for Policy Alternatives characterized a similar situation in its report *Government Involvement in the Innovation Process*, which stated that, "large oligopolistic firms may concentrate their resources on short-term improvements rather than on risky and market-disturbing long-term innovations. Individual consumers face a

[62] "Out with the old year, in with…the same old stuff," *Automotive News,* January 9, 2006
[63] In 1968, the Justice Department accused the Big Three of a conspiratorial effort to "eliminate all competition among themselves in the research, development, manufacture, and installation of motor vehicle air pollution control equipment." The auto companies agreed not to do so in a consent decree. Today, product and price decisions among GM, Ford, and the Chrylser group are routinely parried and matched by one another. When one offers incentives, the others follow. When one designs a muscle car, the others do so as well.

similar problem in that they often lack the information to make wise purchases or the market power to be effective bargainers."[64]

Such market concentration and information asymmetry within the automotive sector has yielded a host of stagnant vehicle designs that are inefficient and dangerous—and frequently contrary to consumer demand. In 2004, 91% of respondents to a Lou Harris poll indicated that they would spend $200-$300 more for safety improvements to new cars, and 83% said that they were in favor of major upgrades to roof safety standards.[65] It follows that many new car buyers might be surprised to learn that their vehicle's roof structure is approximately as strong as the roof on a 1971 model because many automakers have done little to improve the roof crush resistance of cars and trucks in the thirty years since the first standard was issued.

Furthermore, the mechanism by which manufacturers gauge consumer interest in the innovations they choose to market (placing most on the optional list of accessories) is not only inherently flawed, in the case of safety innovations it is patently wrong because it often forces the buyer to choose between safety and economy. Ralph Nader noted in 1965 that "the industry has not recognized the immorality of selling style as part of the basic cost of cars while requiring the buyer to pay extra for safety."[66]

Yet technological innovation, including that related to auto safety, is by definition without real-world success and is therefore difficult to associate with accurate performance data. Modeling and testing only approximate on-road interactions. With

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[64] *Government involvement in the innovation process: a contractor's report to the Office of Technology Assessment*, Center for Policy Alternatives, MIT, 1978, p. 14

[65] "As traffic fatalities hit 13-year high, new Lou Harris poll shows near unanimous public support for government action to improve vehicle safety standards to stem rising tides of death," Advocates for Highway and Auto Safety, July 12, 2004, http://www.saferoads.org/press/press2004/pr_HarrisPoll7-12-04.htm

[66] *Unsafe at Any Speed*, Ralph Nader, Grossman Publishers, 1965, p. 159

only performance estimates, manufacturers, consumers, and regulators cannot precisely evaluate the effectiveness of new technology. So observers may wait years until the precise effectiveness of safety innovations, first appearing in luxury or upmarket models, is corroborated by the crash records of these chosen vehicles. Effective and practical safety technology, years after being introduced to the market, might now become standard equipment by means of law, regulation, or common agreement.

The viability and efficacy of fuel-saving innovations are less dependent on real-world observations, with results more accurately predictable than safety technology, but a similar problem of consumer awareness persists. The average consumer is not knowledgeable enough to interpret mileage ratings relative to measurement inaccuracies, automakers' technological potential, or producers' marginal manufacturing costs, and so he is ill-equipped to judge fuel economy improvements. Prudent car buyers know which models get better gas mileage than others, and gasoline price spikes may shift consumer preference to less fuel-consuming vehicles, but it is doubtful that the typical consumer can evaluate absolute mileage ratings and the underlying engineering. Without such a critical analysis, consumers cannot gauge the automakers' effort and ability to produce highly efficient and economical vehicles. Most car buyers have no way of knowing how easy or difficult it might be for manufacturers to design vehicles that achieve 10 percent or 100 percent better fuel economy, or what those increases might cost. The tradeoff between horsepower and fuel economy is also only partly understood by consumers.

In the gulf of knowledge between what consumers can be reasonably expected to understand about passenger vehicle design and what the auto industry actually builds lies the National Highway Traffic Safety Administration, tasked with ensuring the safety and fuel economy of cars and trucks sold in the US.

5. The Federal Regulator

If the industry is somewhat rigid, then NHTSA is ossified. Even the agency's own engineers admit to a lack of speed and effectiveness. Dr. Joseph Kanianthra, the Associate Administrator of Vehicle Safety Research at NHTSA, says that, "in my own personal opinion we are a bit slow on the issue, and we must move ahead if we are going to commit to safety."[67]

Kanianthra's comments echo NHTSA's performance on such key safety provisions as airbags, tire pressure monitoring, and roof crush resistance, all of which have required the intervention of lawsuits or acts of Congress to seriously advance. The agency's sluggish pace can in part be traced to anemic budgets and the inability to act independently of the White House's deregulation ideology in implementing its federal statutes. NHTSA ineptitude is not, however, due to a lack of authority. In specific regard to technology and innovation, a U.S. Court of Appeals ruled that NHTSA is "empowered to issue safety standards which require improvements in existing technology or which require the development of new technology, and it is not limited to issuing standards based solely on devices already fully developed."[68]

It is useful, therefore, to analyze the degree to which NHSTA has successfully acted in a technology-forcing capacity, or a promoter of auto safety and efficiency innovation. In so doing, the governmental response to technological innovation can be characterized and opportunities for improving the industry-regulatory interaction to

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[67] "Automakers urged to address car-SUV crashes," Jeff Plungis, Detroit News, April 14, 2005
[68] *Chrysler Corp. v. Dept. of Trans*., 472 F.2d 659, 673 (6th Cir. 1972).

promote greater and swifter advances in automotive safety and efficiency can be identified.

Four Federal Motor Vehicle Safety Standards

FMVSS 208 — Occupant Crash Protection

Safety standard 208 has been the subject of perhaps the most attention and contention of any motor vehicle standard, having been proposed, amended, revoked, re-enacted, and argued all the way to the Supreme Court.

In its first incarnation (1967), standard 208 simply required the installation of seat belts in passenger vehicles sold in the US. Due to low belt usage rates, however, the standard was revised in 1971 to require the use of passive restraints that would provide crash protection in the absence of any action by vehicle occupants. Two types of passive restraints: airbags and automatic seat belts, satisfied the early passive restraint rules.

The threat of an airbag requirement provoked a hostile reaction from industry[69] and for the next 20 years standard 208 treaded in a political and regulatory quagmire. In 1984, Ford Motor Company settled a lawsuit after an 18-year-old crash victim alleged that Ford should have installed an airbag in her Pinto. The victim was rendered quadriplegic in a frontal collision and Ford agreed to pay $1.8 million.[70] Publicity from

[69] See transcript from audio tapes of a White House meeting between Henry Ford II, Lee Iacocca, John Ehrlichman and President Nixon, April 27, 1971, National Archives; audio tapes of a telephone call between John Ehrlichman and Secretary of Transportation John Volpe, April 30, 1971, National Archives; *Motor Vehicle Manufacturers Association v. State Farm Mutual*, 463 U.S. 29 (1983)

[70] *Lifesavers: CJ & D's guide to lawsuits that protect us all*, Mulligan, M., Gottlieb, E., Center for Justice and Democracy, 2002, http://www.centerjd.org/free/Lifesavers.pdf

the case and others like it helped force Ford to begin offering airbags as optional equipment on some models.[71]

Ultimately, Congress included a passive safety provision in the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), ordering NHTSA to issue a rule requiring mandatory installation of airbags no later than 1993. By this legislation NHTSA was to require the installation of driver and passenger airbags in 95% of each manufacturer's passenger cars no later than September 1, 1996. Full compliance would be required in the following model year. Slower implementation timetables were issued for light trucks.

As a result of the delay to incorporate an airbag requirement into FMVSS 208, by the time NHTSA issued its final rule in 1994, airbag technology had been studied for 40 years. The first patent for an inflatable "safety cushion" was granted by the United States Patent Office in 1953 to John Hetrick of Newport, Rhode Island.[72] The automotive industry experimented with engineering problems of bag structure and means of inflation throughout the 50s and 60s, mostly in secret.[73] A NASA contract to the Martin Company and Carl Clark in 1964 provided the first public research demonstration of the potential safety benefit of airbag restraints.[74] In the 1970s, GM debuted the first commercial application of the airbag, offering it as an option in some 1974 Buicks, Oldsmobiles and Cadillacs, following a production run of 1,000 prototypes in 1973 Chevrolets.[75]

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[71] Ibid
[72] "GM's airbag concept inflated slowly," Auto News, August 2, 2004
[73] *Unsafe at any speed,* Nader, R. Grossman Publishers, 1965; Life Magazine article 1964
[74] Discussion with Carl Clark, January 16, 2006
[75] "GM to offer bags on some '74s," *Automotive News*, February 19, 1973

So the 1994 NHTSA revision of FMVSS 208 was a diffusive rule (not an innovative one), mandating the use of technology which first appeared—albeit as an option—in the commercial market 21 years earlier.

2000 FMVSS 208 Revision — Advanced Airbags

Following the occurrence of heavily publicized injuries to children and small-stature persons caused by early airbag technology, NHTSA again revised FMVSS 208 in 2000 to include requirements for so-called "advanced airbags." As before, NHTSA began the rulemaking process but its slow pace inspired Congress to pass a statutory impetus in 1998 directing a specific timetable for the agency to rewrite FMVSS 208, "to improve occupant protection for occupants of different sizes, belted and unbelted…while minimizing the risk to infants, children, and other occupants from injuries and deaths caused by air bags, by means that include advanced air bags."[76] NHTSA issued its final advanced airbag rule on May 12 2000.[77]

Rather than actually promoting advanced airbag technology, the final form of the 208 revision required only elementary changes to the conventional airbag control system. Additionally, while the 2000 FMVSS revision broadened the class of protected occupants and crash events it actually *lowered* the test vehicle speed for the most severe configuration. (The test speed for a crash into a rigid barrier with an unbelted median-sized male dummy was lowered 5 mph from 30 mph to 25 mph after the agency sided with manufacturers' arguments that lowering the test speed would allow automakers to

[76] Public Law 105-178, title VII, § 7103(a), 112 Stat. 465-66 (1998)
[77] 65 Federal Register p. 30680, May 12, 2000; NHTSA 00-7031

reduce airbag-injury risks without sacrificing severe crash protection.)[78] The 2000 FMVSS 208 standard revision did not, in fact, promote advanced airbags, it mandated *depowered* airbags that only inflate when a heavy object (similar in weight to a teenager or adult) occupies the seat.

A summary of the tests required by the airbag standard is presented in table 1.

Table 1. Protected Crash Event Configurations	
Pre-2000 FMVSS 208	*2000 FMVSS 208 Revision – Advanced Airbags*
Unbelted 50th percentile male dummies in 30 mph barrier or sled test simulation*	Unbelted 50th percentile male and 5th percentile female dummies in 25 mph rigid barrier
Belted 50th percentile male and 5th percentile female dummies in 30 mph rigid barrier	Belted 50th percentile male and 5th percentile female dummies in 30 mph rigid barrier
	Belted 5th percentile female in 25 mph offset deformable barrier
	1, 3, 6 yr-old child dummy in static airbag inflation test

FMVSS Standard 208 pre and post-2000
*NHTSA allowed manufacturers to use a decelerating sled test in the interim period between the beginning of the rulemaking and its completion as a temporary means of certifying depowered airbags, a quick fix for the problem of airbag induced injury according to the agency. Sled tests slow the vehicle quickly but do not crash it.

The advanced airbag revision did not require improved crash protection for severe crashes or sophisticated countermeasures to minimize airbag-induced injury, for interrelated reasons. First, the standard reduced the maximum crash test energy by 30 percent, eroding the upper bound of occupant protection for all persons. Second, because the most aggressive airbag deployments (high speed crashes with unbelted median-sized adult males) can be depowered to meet this new standard, the requirement that small females (5th percentile) be protected and uninjured in the same crash configuration is less stringent. Third, because NHTSA itself found that existing vehicles could meet the proposed low risk static deployment tests with "the addition of a weight sensor," the

[78] Advanced Airbag Final Rule, NHTSA Docket 00-7031, p. 65

standard does not in fact require the installation of advanced airbag technology, only basic modifications.[79]

A truly advanced airbag standard would require manufacturers to equip vehicles with airbag systems that can detect occupant size, occupant position, crash severity, and dynamically alter the inflation characteristics of the restraint according to such variables. A range of bag inflation and energy absorption profiles would be possible from such a system. The airbag system would protect—and not injure—children, small stature females, adult males, and out of position occupants in low speed and high speed crashes.

Even some of the earliest commercial airbag designs were manufactured to more advanced performance standards than is required by the 2000 advanced airbag rule. In fact the very first mass-produced airbags, made by General Motors from 1973-1976, featured dual level deployment systems that inflated less aggressively in low speed collisions. Harold Mertz, senior GM engineer, discussed the automaker's early airbag systems at a public hearing on airbag-induced injury and stated that, "it just makes logical sense to deploy in proportion to the crash severity."[80] In 1988, Mercedes-Benz started selling vehicles engineered with dual thresholds, setting different levels for airbag deployment based on collision speed. These dual threshold airbags inflated in 12 mph collisions for unbelted occupants but not until 18 mph for belted occupants.[81] By the time NHTSA began considering the advanced airbag standard, in the late 1990's, other technologies to improve airbag performance—like radar pre-crash sensing and occupant

[79] *Final economic assessment: FMVSS No. 208 Advanced Air Bags*, Office of Regulatory Analysis & Evaluation, NHTSA, May 2000, section E-3

[80] Report of Proceedings, Public Forum on Air Bags and Child Passenger Safety, National Transportation Safety Board, March 1997, p. 196

[81] Ibid, p. 275

size detection—had been known to the agency and to the industry for some time.[82] In fact, the Minicars Research Safety Vehicle (RSV), contracted by NHTSA in 1975, employed a radar-based object detection system very similar to pre-crash sensors that major automakers would begin publicly investigating decades later.[83] That the FMVSS 208 revision did not require the implementation of these technologies—or even the dual stage, dual threshold features that were available in much earlier vehicles, is certain proof that the advanced airbag standard did not meet its statutory mandate.

On December 17, 1997, while NHTSA was still finalizing the 208 rule revision, the agency sent an information request to major automakers to investigate their progress on the underlying technology necessary for advanced airbag systems. Table 2 presents a summary of the replies to the information request, in which each automaker indicated their progress on specific technology. As the table summarizes, a number of these devices were not available before the 1998 model year. Also note that weight/pattern recognition, though reported to be deployed in MY 2000, was actually first available commercially in MY 2001 vehicles.[84]

Judging from the initial research—but lack of commercial deployment—of pre-crash sensors (shown in table 2), NHTSA had the potential to issue a truly innovative advanced airbag rule in 2000 but chose not to do so. Equipping vehicles with pre-crash sensors enables a vehicle to anticipate not only the likelihood of an imminent crash but the severity of it as well. The airbag inflation can then be varied relative to the force of

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[82] Ibid, p. 305
[83] *Research Safety Vehicle: Final Briefing*, Minicars, Inc., 1980
[84] "Delphi Develops World's First Commercial Passenger Occupant Detection System for Required Advanced Airbag Systems," news release from Delphi Automotive Systems, Oct. 16, 2000. http://www.prnewswire.com/cgi-bin/stories.pl?ACCT=104&STORY=/www/story/10-16-2000/0001338525&EDATE=

the impending crash, and in accordance with information from other inputs like occupant weight and pattern recognition sensors.

As the final rule was written, the required tests in the 208 revision did not necessitate any advanced crash-detection technology or mandate a dynamically variable airbag system. In fact, the practical result of the FMVSS revision was to require a binary solution, either (1) the deployment of airbags if a heavy occupant is in a seat or (2) no deployment of airbags if a light weight occupant (or no occupant) is in the seat. The 2000 FMVSS 208 revision, for advanced airbags, was not innovative.

Table 2

Technology	**Manufacturer Deployment Based on IR Response**	**Discussion of Activities which Post-Date the IR**
Buckle Sensors	Mercedes MY 1990-1998	Honda MY 1999, others plan to implement in MY 2000
Pre Tensioners	Numerous, MY 1990-1997	
Load Limiters	Numerous, MY 1990-1998	
Web Clamps	Numerous, MY 1990-1997	
Advanced Crash Sensing	Not requested in IR	Several will soon add this tech.
Multi Stage Inflation	None reported	Honda MY 1999, other to begin
On/Off Switch	GM MY 1997, Ford MY 1997, Chrysler MY 1998	
Child Seat Sensors	Mercedes MY 1998	
Seat Position Sensors	None reported	One will install in MY 2000
Weight/Pattern Recognition Sensors	None reported	Manufacturers will begin installing in MY 2000. Wide use expected soon.*
Capacitance Sensors	Not requested	Some may be in use, research ongoing
Pre-crash Sensors	**None reported**	**Research underway**
Infared Sensors	Not requested	Under research
Inflatable Knee Bolsters	None reported	Some manufacturers have used these devices and others are planning their use

Data from *Air Bag Technology in Light Passenger Vehicles*, Office of Research and Development, NHTSA, 2001.

Tire Pressure Monitoring Standards

Following the much publicized Ford-Firestone tire failure and rollover disaster, Congress enacted the Transportation Recall, Enhancement, Accountability and Documentation (TREAD) act in 2000. TREAD directed NHTSA to issue a rule requiring the addition of a monitoring system to alert drivers of improper and dangerous tire pressure levels.

In response to the TREAD mandate, NHTSA promulgated a final rule in 2002 which allowed manufacturers to comply by means of either (1) a direct pressure monitoring device or (2) an indirect system relying on wheel speed differentials observed by the anti-lock brake system. The indirect system presents numerous drawbacks to a direct approach—noted by NHTSA in its Notice of Proposed Rulemaking—including the inability to detect the following underinflated conditions: (1) two underinflated tires on the same axle, (2) two underinflated tires on the same side of the car (3) all four underinflated tires on the vehicle and (4) small pressure losses (between 15-40 psi, or 20%-30% of standard tire pressure).[85]

A U.S. Court of Appeals overturned the rule, stating that indirect TPMSs would not comply with the TREAD act. In April 2005, NHTSA issued a new rule requiring direct pressure monitoring in all four tires.

Direct tire pressure monitors are microelectromechical transducers, tiny devices typically comprised of a piezoelectric pressure sensor, temperature sensor, voltage sensor, accelerometer, microcontroller, radio-frequency circuit, antenna, and battery.[86] Part of the microelectrical mechanical systems (MEMS) family of technology that

[85] Notice of Proposed Rulemaking, 66 Fed. Reg. No. 144, 38982, NHTSA Docket 2000-8572
[86] "Pumped Up," *Mechanical Engineering*, April 2005

combines mechanical and electrical systems in computer-chip dimensions, mandatory direct tire pressure monitors on every vehicle will provide a huge boost for the fledgling MEMS industry. *Mechanical Engineering* magazine estimates “an instantaneous market for perhaps 70 million MEMS devices a year”.[87] Currently, 90 million MEMS accelerators are installed per year for use as airbag triggers.[88]

According to the Alliance of Automobile Manufacturers, the first direct TPMS appeared on the 1997 Chevrolet Corvette.[89] By the time NHTSA issued the revised rule in April 2005 (requiring direct measurement) 18% of the cars sold by manufacturers in the Alliance were equipped with the devices.[90]

Thus the tire pressure monitor standard issued by NHTSA will result in technological diffusion, not innovation.

FMVSS 216 – Roof Crush Resistance 1971 Roof Crush Resistance Rule

The safety standard affecting roof strength has not changed since the time it was enacted in 1971, although NHTSA issued a preliminary revision in 2005. FMVSS 216, roof crush resistance, originally specified a maximum deformation of not more than 127 mm (5 inches, measured by the travel of the loading plate) at a force equal to 1.5 times the unloaded weight of the vehicle, applied to one side of the roof with a flat platen oriented at a 5 degree angle in quasi-static loading.

[87] Ibid
[88] Ibid
[89] “Tire Pressure Monitors Will be Added to Cars,” *Los Angeles Times,* April 8, 2005
[90] Ibid

NHTSA released a study in 1989 evaluating the performance of the 1971 roof crush standard.[91] By normalizing the crush depth results for make and model and comparing the resultant crush depth index across model years, a roof crush trend was determined. According to the report,

> Cars of the mid 1960s actually had the strongest roofs on the tests, with a normalized average crush depth of -0.7. In the later 1960s, large cars emphasized a look with a wide, flat roof. That resulted in weaker roof crush performance, with a normalized crush depth of +0.9 in model year 1970. From model year 1974 onwards (post-Standard 216), roof crush resistance is better than in 1970 and the normalized score is usually closer to 0 (average strength). A more detailed look at the laboratory test results show that most cars easily exceeded the requirements of Standard 216, even before the standard took effect.

Since FMVSS 216 required no technological advance in new vehicles in order to "easily" achieve compliance, it follows that the standard was neither technologically innovative nor diffusive.

2005 Roof Crush Resistance Revision

Following the issuance of the first roof crush rule, interest in reducing the frequency of injuries due to rollover crashes (which accounted for one third of occupant fatalities in 2002) prompted NHTSA to investigate upgrading the roof crush standard. During the recent deliberation, NHTSA was presented with several opinions by automakers, (including Ford, GM, Daimler-Chrylser and Nissan), that there was no benefit to limiting headroom reduction, or roof crush, in a rollover test.

Ford submitted evidence to support this claim in 1999 based on its interpretations of dolly rollover tests (that initiate rollover by accelerating a vehicle sideways into a short

[91] *An Evaluation of Door Locks and Roof Crush Resistance of Passenger Cars*, DOT HS 807 489, NHTSA, 1989

barrier).[92] Ford documented that the peak compressive forces and head moments (bending) occurred prior to observable roof/pillar deformation. Ford surmised that because the peak forces occurred before the roof and pillars appeared to deform, there can be no causal link between roof deformation and dummy-experienced loads. Moreover, because occupant injury is dependent on these same forces, there must be no relationship between occupant injury and roof intrusion.

However, another study of the same data came to a more precise, and contrary, conclusion. Martha Bidez, a professor of biomedical engineering at the University of Alabama at Birmingham, led an examination of the Ford rollover test data (including accelerometers, dummy load cells and video stills), which became public through litigation. Yet instead of relying on the highly subjective "observable roof/pillar deformation" to determine the onset of structural intrusion (as Ford had done) the Bidez team analyzed accelerations on the driver and passenger side B pillar. Not only does the Bidez methodology afford a quantifiable profile of roof crush, it defines it in a more precise way, as accelerometer data was recorded at 12,500 Hz and 25,000 Hz, compared to high speed video capture that recorded visual images at a rate of 500 frames/sec (~500 Hz).[93]

While both the Ford and the Bidez team agreed that peak compressive neck forces occurred at 540 ms, the Bidez investigators found that objective roof crush/roof intrusion occurred at 513 ms compared to the "observable roof/pillar deformation" Ford witnessed

[92] *Rollover Occupant Kinematics & Roof Pillar Deformation*, Presentation by Ford Motor Co., NHTSA-1999-5572-75
[93] *Roof crush as a source of injury in rollover crashes*, Bidez, M., Cochran, J., King, D., March 30, 2005. Available from Public Citizen

at 590 ms. So the Bidez team finds the sequence of two critical events, roof crush onset and maximum compressive neck forces, in reverse order.

In addition, Bidez noted that the passenger dummy experienced greater loads than the driver dummy, consistent with NHTSA's own field data showing greater injury to far-side occupants in rollover crashes.[94] Moreover, the loads experienced by the passenger dummy exceeded documented failure loads of the human spine. Bidez thus concludes that "Roof crush into the survival space of restrained dummies was the direct cause of neck loads, which were predictive of catastrophic injury in rollover crashes."[95]

Perplexing throughout this exercise is the understanding that while Ford had the ability to investigate roof crush in the same manner as Bidez (using objective data), they opted for a subjective and less precise approach. In doing so, Ford representatives obscured from NHTSA the need for more advanced rollover prevention and roof crush protection technology.

Subsequently, in August 2005, NHTSA issued a proposal to upgrade the roof crush resistance standard that notably (1) increases the loading requirement to 2.5 times the weight of the vehicle (2) replaces the plate movement limit with a limit on headroom reduction (the distance between the crushed roof and a 50th percentile male dummy) (3) extends the rule to include vehicles up to 10,000 lbs., and (4) eliminates a previously imposed load ceiling for passenger cars.[96] NHTSA estimates the revision will save 13 to 44 lives per year.[97]

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[94] Ibid
[95] Ibid
[96] Roof Crush Resistance, NPRM, NHTSA-2005-22143
[97] Ibid

The revised rule does not mimic real life rollover crashes or spur innovative structural improvements to passenger vehicles. Further, because it now measures the headroom between the roof and a 50th percentile male dummy, on average it will allow more deformation than the previous rule did. (NHTSA found that vehicles, on average, had over 7 inches of headroom between the roof and the test dummy, compared to the previous limit of 5 inches of travel.)[98] Additionally, because the proposed rule applies force only to one side of the roof—at a shallow role and pitch angles, and at a steady rate—a substantial part of the load is supported by the windshield and B-pillar. This has led automakers to manufacture vehicles that pass the test by relying on stiff windshield glazing and its bonding to provide over 30 percent of roof strength.

In a rollover crash, however, the windshield is typically fractured during the first roof impact. As the vehicle completes a roll, side pillars and roof panels now more easily buckle and deform into the occupant compartment and fracture side windows, causing occupant injury and creating portals for occupant ejection. Typically, the trailing side (far side) of the roof suffers substantially more damage in a rollover, which explains why far-side occupants suffer more injuries and fatalities in a rollover.

But the revised standard does not account for these effects—or any realistic behavior that accompanies a dynamic rollover event—and is therefore deficient. The inadequacy of the proposed roof crush test is corroborated by the modest predicted benefit (at most 44 fatalities prevented) estimated by NHTSA.

If NHTSA had chosen to upgrade FMVSS 216 by requiring two sided testing or a dolly rollover test (already on the books as an optional test in FMVSS 208), the standard would no doubt have encouraged the production vehicles with much stronger—and

[98] *Quasi-static and dynamic roof crush testing*, Rains, G.C., Van Voorhis, M.A., NHTSA, June 1998

safer—roof structures. As it stands, the proposed 216 revision will not even approach the current paradigm for rollover protection, the Volvo XC90, with a roof strength of 3.5 to 1, which can sustain three rollovers without deforming the roof or fracturing the windshield.

More than 10,000 people die in rollover crashes every year, but NHTSA is prepared to issue a standard that, by its own admission, would only save 44 lives at most. The long-awaited and anemic revision to the roof crush standard is neither innovative nor diffusive.

Summary of NHTSA's Role in Five Major Rulemakings

<u>FMVSS 208 – Airbag Revision</u>

NHTSA was ordered by Congress in 1991 to issue a rule that required airbags be standard equipment in cars and light trucks, as manufacturers were already partially doing. The first rule took effect over 40 years after the invention of the first airbag.

<u>FMVSS 208 – Advanced Airbag Revision</u>

In 2000, NHTSA revised standard 208 to protect lighter occupants and reduce the frequency of airbag-induced injury. NHSTA's solution resulted in an on/off configuration: the airbag inflates (less powerfully than before) if a heavy object is seated or does not inflate if sensors detect a light occupant or empty seat. Other technology in development at the time of the revision had the potential to make airbag systems much more dynamic, but NHTSA did not require their deployment.

Tire Pressure Monitoring Rule

Congress ordered NHTSA to write a new safety standard, a tire pressure monitoring rule, following the Ford-Firestone fiasco. NHTSA's first attempt, permitting an indirect monitoring system relying on existing ABS technology, was rejected by the courts. NHTSA rewrote the rule to require direct monitoring by advanced—but not innovative—MEMS pressure sensors.

FMVSS 216 – Roof Crush Resistance

NHTSA issued a roof crush resistance rule in 1971 and the agency later concluded that "most cars easily exceeded the requirements of Standard 216, even before the standard took effect."

FMVSS 216 – Roof Crush Resistance Revision

NHTSA proposed a revision of the roof crush resistance standard in 2005, 34 years after it was written. The proposed standard increases the loading requirements but is only estimated to prevent at most 44 fatalities per year. The proposal does not encourage the type of life-saving roof manufactured by some automakers.

The Entrepreneurs – Contests and the Small Business Innovation Research (SBIR) Program

On October 4, 2005, an aerospace team led by Burt Rutan and Paul Allen won the Ansari X Prize, which offered a $10 million reward to the first privately funded team to successfully pilot a manned flight to the threshold of space and return to earth safely.[99] As the X Prize Foundation notes, some of the earliest aviation achievements—and indeed much of the early aviation industry—was sparked by contests, including the challenge to fly nonstop from New York to Paris, met by Charles Lindbergh in 1927.

Prizes offered for technological accomplishments have the effect of exponentially increasing private research and development expenditures. The prize for the transatlantic flight, $25,000, inspired nine teams to spend more than $400,000 on the project.[100] Paul Allen alone invested more than $20 million to win the $10 million X Prize.[101] Even before modern aviation, some of the most indispensable innovations were spurred through a prize system, including the chronometer (to accurately measure longitude while sailing),[102] and canned food (requested by Napoleon's army).[103]

More recently, the EPA, together with 25 utilities, offered a $30 million Super Efficient Refrigerator Prize (SERP) for the first manufacturer who could design and mass-produce a chlorofluorocarbon-free refrigerator 25 percent more efficient than

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[99] X-Prize Foundation Fact Sheet, http://www.xprizefoundation.com/about_us/fact_sheet.asp
[100] X-Prize Foundation Fact Sheet, http://www.xprizefoundation.com/about_us/fact_sheet.asp
[101] "Space Ship One wins $10 million X Prize," Alan Boyle, MSNBC, October 5, 2004, http://www.msnbc.msn.com/id/6167761/
[102] "Longitude clock comes alive," Julianna Kettlewell, BBC News, March 11, 2002, http://news.bbc.co.uk/1/hi/sci/tech/1864737.stm
[103] "The canning process: old preservation technique goes modern," Dave Blumenthal, *FDA Consumer*, http://www.fda.gov/bbs/topics/CONSUMER/CON00043.html

comparable 1993 models.[104] Whirlpool Corporation won the "Golden Carrot" contest with a creatively redesigned refrigerator, replacing refrigerant CFC-12 with HFC-134a and a host of other technological improvements.[105] But the payout scheme forced Whirlpool to sell 250,000 refrigerators by July, 1997 to receive the entire prize, and sales of the unit were sluggish.[106] Whirlpool actually discontinued the model before the deadline expired.[107]

Though the refrigerator itself was not commercially successful, the Golden Carrot award provided Whirlpool, and energy efficient appliances, with significant publicity and encouraged other manufacturers to follow suit. [108] The one prize-inspired design did not live on, but energy-efficient siblings soon came to market.

Similarly, the Department of Energy and the Defense Department have initiated contests challenging teams to engineer vehicles that demonstrate technology which drastically improves the performance of passenger vehicles. The DOE contest, FutureTruck, was a cooperative effort between Argonne National Laboratory, domestic automakers, and 15 North American universities. In the first two years of the program, 2001 and 2002, General Motors cosponsored the competition and supplied Chevrolet Suburbans to each university team, which was tasked with reducing emissions and improving efficiency by at least 25 percent.[109] From 2003 to 2005, Ford assumed the role

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[104] "The race to make the fridge of the future," Home Energy Magazine Online, January/February 1993, http://homeenergy.org/archive/hem.dis.anl.gov/eehem/93/930116.html
[105] Ibid
[106] *How effective are prizes as incentives to innovation? Evidence from three 20th century contests*, Davis, L., Davis, J., presented at the DRUID summer conference 2004 on Industrial Dynamics, Innovation and Development, June 2004
[107] Ibid
[108] Ibid
[109] FutureTruck, http://www.transportation.anl.gov/research/competitions/futuretruck/

of industry sponsor and offered up Explorers for the modifications.[110] Competition designs were evaluated through various laboratory and on-road tests, though no monetary award was offered. FutureTruck has ended, though a similar contest, Challenge X, sponsored by GM and DOE, continues. Information provided by Challenge X notes that the Department of Energy has teamed with industry and academia to sponsor contests more than two dozen times since 1987.[111]

The Defense Department takes a slightly different approach, awarding $2 million from the Defense Advanced Research Projects Agency in 2005 to any team that could build an autonomous vehicle capable of traversing a 131.2 mile course over desert terrain through its "Grand Challenge." Team entrants ranged from university students to independent hobbyists to corporations. Vehicles that were invited to compete in the final race exhibited novel and sophisticated control algorithms, high-speed video imaging, laser-based range finding, GPS navigation, and other related technology. The winning team from Stanford completed the course in a time of 6 hours, 53 minutes.[112]

For its part, NHTSA sponsors no contests like FutureTruck or the Grand Challenge, which necessarily limits the agency's exposure to the type of prize-inspired innovations encouraged by DOE and DARPA. While NHTSA's joint R&D programs typically focus on large manufacturers, a contest might open the door for many small entrepreneurs who are commonly overlooked. In fact, the agency's Small Business Innovation Research (SBIR) program, which funds research proposals for entrepreneurs, is intended to accomplish just such an outreach, but the program has been hampered in recent years due to cost constraints.

[110] FutureTruck, http://www.transportation.anl.gov/research/competitions/futuretruck/
[111] About Challenge X, http://www.challengex.org/about/index.html
[112] http://www.darpa.mil/grandchallenge/

From 1999 to 2005, NHTSA awarded no more than 3 SBIR grants per year, and never approved any of the projects to advance beyond phase I, where funding is limited to $100,000.[113] Unfortunately, this sum lies between what NHTSA considers a moderate amount and what engineering firms consider barely useful for innovative product development. According to NHTSA engineers, the SBIR program is noble but difficult to fund beyond the initial phase given the agency's limited R&D budget. However, SBIR has led to the successful development of vehicle safety technology in the past, including a magnetohydrodynamic sensor to detect angular rotation in crash dummies.[114]

Currently, the importance of reaching out to even smaller innovators might be totally lost on NHTSA, which has not employed an inventor contact since Dr. Carl Clark, a Physical Scientist in the Office of Crashworthiness Research, retired from the agency in 1990.[115]

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[113] US DOT Small Business Innovation Research (SBIR), http://www.volpe.dot.gov/sbir/
[114] Telephone conversation with Steve Summers, NHTSA Vehicle Safety Research, February 15, 2006
[115] Telephone conversation with Eric Bolton, NHTSA communications office, June 15, 2005

6. Current Auto Safety Technology Review

The following discussion of various auto safety concerns and prophylactic technologies is organized according to five pertinent categories: visibility, chassis and body, occupant restraint, control systems, and sensors.

Visibility	Chassis and Body	Occupant Restraint	Control Systems	Sensors
Hydrophobic glass	Footwell design	Seat belt use reminders	Electronic Stability Control	Weight and passenger detection
Adaptive headlights	Passenger compartment integrity	Seatbelt Pretensioners and Retractors	Gyroscopic Roll Sensing	Driver alertness monitoring
Head Up Display	Pedestrian safety	Improved 3-point belts	Electronic brake assist	GPS systems
All-weather head lighting system	Commercial truck underride protection	4-point belts	Extra-vehicular object detection	Event data recorders
	Bumpers	Advanced seatbelt materials	Lane departure and lane keeping	Biometrics
	External Airbag Bumpers	Inflatable seatbelts		
		Headrest geometry and active headrests		
		Integrated child seats		
		Airbags – side, lower extremity		
		Side laminated Glass		

Visibility

Hydrophobic Glass

Hydrophobic coatings bond to glass at the molecular level and force water to bead up and roll off the surface. In studies conducted by the University of Michigan Transportation Research Institute, hydrophobic coatings decreased the minimum visual angle resolved by 50% and reduced driver response times by more than one second.[116] The study notes that "in more practical terms, visual performance improved in the treated-nighttime conditions to approximately the level of performance in the untreated-daytime condition."[117]

Until recently, automotive hydrophobic coatings were only effective for weeks or months at a time. Newer products utilizing nanoscale molecules remain useful for up to five years and 30,000 miles.[118] To date, however, no permanently hydrophobic treatments are available for commercial auto glass.

Adaptive Head-lights

Adaptive headlights featured on BMW vehicles actuate the front headlight module with a complex system of motors according to steering, wheel, acceleration and Global Positioning System (GPS) inputs. As a driver enters a turn the adaptive headlight

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[116] *The influence of hydrophobic windshield coating on driver visual performance and response time*, Sayer, J., Meford, M., Flannagan, M., Sivak, M., Kojima, S., University of Michigan Transportation Research Institute, UMTRI-97-31, cited from abstract
[117] Ibid
[118] Email from Harry Stulajter, Nanotec Pty Ltd

system illuminates the bending roadway. Illume LLC has developed a liquid crystal film able to steer and bend light without motorized elements.[119]

Concerns have been raised about the potential for adaptive headlight systems to increase glare or blind drivers in oncoming vehicles. Any adaptive headlight system should balance driving visibility with oncoming glare and would ideally not interfere with other drivers at all.

Head-Up Display

Siemens VDO is the first automotive supplier to offer a head-up display system that allows speed, navigation, and vehicle status indicators to be projected directly onto the windshield.[120] Siemens claims a safety benefit as a result of a 50 percent reduction in the "time needed to absorb information".[121]

All-Weather Head Lighting System

The late professor of optometry at Indiana University, Merrill Allen, O.D., Ph.D., proposed a novel front lighting solution for passenger vehicles that he claimed can reduce dangerous scattering from fog, rain, or snow; and can increase the driver's visual range. Professor Allen's headlight system requires the use of two pairs of lights, a low-mounted pair pointing toward the road and a roof-mounted pair lighting objects above five feet

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[119] Illumeco LLC, http://www.illumeco.com/Technology.htm
[120] Head-up displays, http://www.siemensvdo.com/products_solutions/interior/information-systems/head-up-displays/head-up-displays.htm
[121] Ibid

(including retroreflective signs).[122] The system would put no light in a zone from three to five feet above the roadway.

By creating an unlighted area directly in line with the driver's horizontal visual path, Allen's dual headlight system allegedly reduces harmful atmospheric backscatter that can result when particulates found in fog, rain, and snow attenuate light.[123] According to NHTSA, rain, snow, or sleet is a factor in more than 20 percent of motor vehicle crashes that occur in dark light conditions.[124] Though Allen does not present data to support his claim; the simplicity of his all-weather headlight system merits further investigation.

<u>Chassis and Body</u>

Footwell Design

As the seatbelt usage rate and the fleet penetration of airbag-equipped vehicles increases, more passengers survive motor vehicle crashes, but with serious injuries. Some of the most frequent and debilitating injuries are those to the lower extremities, including the ankle, lower leg, knee, hip and thigh. A 1997 study by the University of Maryland National Study Center for Trauma/EMS noted the special difficulty of characterizing lower extremity injury (LEI) disability using conventional trauma metrics, which were intended to measure risk of death, not quality of life.[125] Though injuries to

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[122] *Forensic Aspects of Vision and Highway Safety*, Merrill Allen, Bernard Abrams, Arthur Ginsburg, Leslie Weintraub, Lawyers and Judges Publishing Company, 1999, p. 137
[123] Ibid, p. 138
[124] *Traffic Safety Facts: 2004 Data*, DOT HS 809 911
[125] *Lower extremity injury among restrained vehicle occupants*, University of Maryland National Study Center for Trauma/EMS, presented at the first annual CIREN conference, October 20, 1997

feet and legs may rank low on injury severity scales, they are often accompanied by poor post-trauma outcomes including permanent physical disability and psychological duress.

Monetarily, the societal cost of lower extremity injuries is approximately $8 billion annually.[126] This pain and suffering may be easily prevented. Structural improvements for the reduction of lower extremity injuries (LEIs) are accessible and straightforward, according to the textbook on vehicle crashworthiness and occupant protection written by the American Iron and Steel Institute: "Perhaps the only solution is to strengthen the footwell to reduce the intrusion and to have a collapsible brake pedal."[127] Indeed, a 2002 University of Maryland study of LEI found that the floor and toe pan were the most frequent injury source, causing 23% of lower extremity injuries.[128] Foot controls accounted for 6% of injuries.[129]

Solutions to reduce floor and toe pan intrusion lie in stronger and stiffer alloys as well as improved body structure design. Less dangerous foot controls can be engineered to either collapse or break in a crash.

Collapsible pedals, such as those found on the Mazda 6, actually pivot away from driver's legs in the event of structural intrusion. A cross member attached to the dash interacts with the out-of-position pedal assembly and causes the accelerator and brake to rotate away from the passenger cabin. According to Edmunds.com, Mazda claims their

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[126] *An Overview of Knee-Thigh-Hip Injuries in Frontal Crashes in the United States*, Kuppa, K., National Highway Traffic Safety Administration, Presented at the 18th International Technical Conference of Enhanced Safety of Vehicles, 2003

[127] *Vehicle Crashworthiness and Occupant Protection*, chapter 6, American Iron and Steel Institute, http://www.autosteel.org/safety_book/index.htm

[128] *Real (leg) injuries, Real People*, University of Maryland CIREN team, presented at the ninth quarterly CIREN meeting, August 22, 2002

[129] Ibid

collapsible pedal design may be the difference "between an ankle that's merely sprained and one requiring a walking cast for 6 months."[130]

Passenger Compartment Structural Integrity

Recently publicized internal GM documents[131] and advanced Volvo design methodologies[132] reveal long known axioms and more recent adaptations of safe vehicular structures. The keys are relatively simple: small car compatibility, strong A and B-pillars, stiff rocker panels (the longitudinal sill below the doors), and reinforced roof members. The results are striking. Video of a Volvo XC 90, built to this paradigm, in a dolly rollover test, shows the SUV rolling over nearly three times without structural buckling or substantial roof or body intrusion.[133]

A high-strength car need not be heavy, either. By careful material selection and placement Volvo has been able to limit the annual body weight increase to 10 kg from platform to platform.[134]

Volvo is following the lead of the steel industry-sponsored UltraLight Steel Auto Body (ULSAB) project, which demonstrated that advanced steel alloys and

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[130] *Preview: 2003 Mazda 6*, Edmunds.com, October 17, 2001, http://www.edmunds.com/reviews/preview/articles/47610/article.html

[131] Minutes from a May 13, 1966 General Motors meeting to discuss work in energy absorption, Report number PG-21773, available at http://www.citizen.org/autosafety/rollover/crashwrth_/

[132] *Safety Cage Design in the XC90*, Jonas Bernquist, Volvo Car Corporation, presented at the Great Designs in Steel Seminar, February 2004

[133] Video of a dynamic rollover test of a Volvo XC-90, http://www.citizen.org/autosafety/images/XC-90Video.avi

[134] *Safety Cage Design in the XC90*, Jonas Bernquist, Volvo Car Corporation, presented at the Great Designs in Steel Seminar, February 2004

manufacturing techniques can be employed to produce a stronger, lighter, and safer steel structure (compared to conventional automotive designs)—and without cost penalties.[135]

The success of Volvo's "safety cage" design previews the next generation of vehicle body structures, which, again, engineers agree must not be heavy to be safe. A 2005 study commissioned by the aluminum manufacturers' association and conducted by Dynamic Research Inc (DRI) decoupled the effects of size and weight on safety, concluding that, in part, maintaining a vehicle's size while reducing weight *lowers* the risk of injury to occupants and other drivers.[136] Future vehicle designs can accomplish the goal of a lighter and stronger body structures by incorporating aluminum (already a feature of the Audi A8 and Jaguar XJ) and advanced lightweight composites (proposed by the Hypercar, Inc. concept, among others[137]).

Cost and performance tradeoffs (e.g. stiffness versus energy absorption) will need to be thoughtfully considered in any vehicle prototype not relying on steel, but the reality of significantly lighter and safer vehicles is within reach.

Pedestrian Safety

Each year approximately 4,500 pedestrians are struck and killed by motor vehicles in the US, accounting for 11% of all traffic fatalities.[138] The problem is greater in more urbanized societies, such as Japan, where pedestrians account for 27% of traffic

[135] *UltraLight Steel Auto Body (ULSAB) Final Engineering Report*, March 1998, http://www.autosteel.org/ulsab/ulsab_eng_rpt_index.htm
[136] *An analysis of the effects of SUV weight and length on SUV crashworthiness and compatibility using systems modeling and risk-benefit analysis*, Kebschull, S., Kelly, J., Auken, R., Zellner, J., Aluminum Association and DRI, 2005
[137] *Design and Manufacture of an Affordable Advanced-Composite Automotive Body Structure*, Cramer, D.R., Taggert, D.F., Hypercar, Inc., Proceedings of the 19th International Battery, Hybrid and Fuel Cell Electric Vehicle Symposium & Exhibition, 2002
[138] *Traffic Safety Facts: 2004 Data*, DOT HS 809 911

fatalities, and Europe, where the pedestrian fatality fraction approaches 30%.[139] Pedestrian fatalities can be even more frequent in poorer countries lacking advanced roadway planning, signaling, signage and education.[140]

While NHTSA lacks any rule or design guideline for pedestrian safety, the European New Car Assessment Program (Euro NCAP) already includes pedestrian safety tests. The Euro NCAP program evaluates 25 mph impacts of leg dummies and headforms at two locations on both bumpers and hoods.[141] A separate star rating for pedestrian safety is assigned to a vehicle based on the results of the leg and headform tests.

The European Commission recently established the first pedestrian safety provisions for motor vehicles. The regulations, which took effect in October 2005, specify force limits and injury criteria for the interaction of legs and heads with bumpers and hoods.[142] More aggressive rules go into effect in 2010.

Foreign manufacturers and suppliers, in turn, are leading the way in the design of vehicles that are less deadly to pedestrians. Honda, in addition to developing the first anthropomorphic dummy to mimic pedestrian kinematics (the POLAR I, in 1998), has announced a novel “pop-up” hood which raises the rear portion of the hood (near the windshield) 10 cm in the event of a pedestrian impact.[143] The raised hood increases the

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[139] “Vehicle Interactions with Pedestrians,” *Accidental Injury: Biomechanics and Prevention*, (Chapter 22), 2000. Saul, R.A., Edlefson, J.F., Jarret, K.L., Marous, J.R.
[140] *Pedestrian traffic injuries in Mexico*, Hijar, M., Vazquez-Vela, E., Arreola-Risa, C., Injury Control and Safety Promotion, 2003. Vol. 10, No. 1-2, pp 37-43
[141] Pedestrian impact test, Euro NCAP website, http://www.euroncap.com/content/test_procedures/pedestrian_impact.php
[142] Directive 2003/102/EC of the European Parliament
[143] “Honda develops pop-up hood for safety; reduces impact to pedestrians in the event of a collision,” Press release, Honda Motor Company, August 24, 2004

space between the relatively forgiving sheet metal hood and hard engine components below.

Even without a pop-up hood, the engine compartment can be designed to maximize the distance between the sheet metal hood and dangerously hard elements like the alternator and engine block. Moreover, a fundamental rethinking of the frontal structure may be required to achieve even greater levels of protection. Given that most vital components are now shrouded under a sheath of metal and plastic, the days of "popping the hood" to inspect an engine are all but over for the average motorist. (Owners of hybrid vehicles are even proactively discouraged from tinkering with the drivetrain.) Engine access today has become a question of fluid replacement (oil, brake, coolant, windshield) for the most part. *Car Design Online* notes that these replenishable reservoirs (or access to them) can be located in a more convenient space.[144] By eliminating the need for frequent operability, the hood could be manufactured of a material and design more optimized to dissipate the energy from pedestrian impact. Hood airbag designs, to protect pedestrians, are also being developed.[145]

One of the most radical pedestrian protection systems was featured on the experimental Minicars RSV, which had a retaining bar that deployed vertically from the bumper after a pedestrian had been thrown onto the hood, keeping the pedestrian on top of the vehicle and preventing him from being tossed back onto the roadway as the vehicle decelerated.[146]

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[144] Car Design Online, Pedestrian Safety, http://www.cardesignonline.com/safety/pedestrian-safety.php
[145] Discussion with Carl Clark, January 16, 2006
[146] *Research Safety Vehicle: Final Briefing*, Minicars Inc., 1980

Commercial Truck Underride Protection

Federal Motor Vehicle Safety Standard 223, rear impact guards, specifies the size and strength of guards mounted to the rear of commercial truck trailers that are designed to prevent light duty vehicles from riding under the trailer during a collision. Unfortunately, the standard allows 305 mm of underride (the horizontal distance between the guard and the rear of the trailer). This clearance facilitates easier docking and cargo loading, but compromises the safety of motorists in cars. The Impact Project, a partnership between the State University of Campinas (Brazil), General Motors-Brazil, and Mercedes-Benz-Brazil, recommends eliminating any allowable underride distance between the guard and the rear edge of the trailer.[147]

Further, no lateral or side guard protection is required by the Federal Motor Vehicle Safety Standards, even though 16 percent of fatal vehicle crashes occurred at the sides of large trucks, according to the Underride Network, an issue-specific safety group.[148] Europe has required some form of side guard protection for large trucks since 1989.[149] An effort by NHTSA and truck manufacturers to improve both rear and side underride protection seems long overdue, especially considering that Congress investigated the possibility of implementing European-style bumper guard in the 1960's, only to be thwarted by the Jimmy Hoffa-led Teamsters and the trucking industry.

Bumpers

Although conventional bumper structures are not intended to significantly contribute to vehicle crashworthiness or protect vehicle occupants in crashes, bumpers

[147] The Impact Project, http://www.fem.unicamp.br/~impact/standards.htm
[148] http://www.underridenetwork.org/indexpage.html
[149] Directive 89/297/EEC, Lateral protection (side guards) of certain motor vehicles and their trailers

fulfill a safety function by shielding fuel, cooling, exhaust, and lighting/signaling systems from damage. As such, vehicle owners benefit from a bumper that does not damage easily or require frequent repair or replacement.

The first bumper standard issued by NHTSA required that bumpers sustain only cosmetic damage in a 5 mph collision. In 1982, however, the agency, under the auto-industry friendly Reagan administration, rolled back the requirements and allowed unlimited bumper damage in a 2.5 mph test as long as no damage to other vehicle systems or body panels occurs.[150] Today, some manufacturers continue to trade on the old standard, marketing "5 mph bumpers."[151]

Overall, the 2.5 mph bumper standard—petitioned for by automakers—resulted in significantly lighter and weaker bumper designs that are easily damaged in low speed collisions. The Insurance Institute for Highway Safety reported that 5 of 6 model year 2004 midsize sedans tested in 5 mph collisions earned poor or marginal bumper ratings by IIHS metrics. The average damage per test for all 6 tests was $741.[152] These bumpers do not incorporate what Mike Ciccone, special projects coordinator for IIHS, calls the "main elements" of effective bumper design, "overhang, energy-absorbing material and a strong enough bumper beam."[153] Whether or not the design is old or new, without attention to these components, bumpers will damage easily, incurring costly repairs and compromising the protection of vital safety systems.

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[150] *An evaluation of the bumper standard – as modified in 1982*, DOT HS 807 072, February 1987
[151] Features and Options, Kia Spectra, http://www.kia.com/newspectra/spectra-features.php
[152] "Five of 6 midsize cars earn low ratings in 5 mph crashes to test the bumpers," news release, IIHS, February 29, 2004
[153] "Bumper battleground—automakers, insurers continue to fight over standards," Drew Winter, Ward's AutoWorld, July 1, 1998

External Airbag Bumpers

Under contract from NHTSA in the 1970's, Research Safety Vehicles (RSVs) were designed and built to withstand much greater crash forces than current passenger vehicles are required to, in part by employing a frontal structure capable of absorbing significant crash forces. For example, test results of the Minicars RSV showed that passengers would walk away from a 50 mph frontal crash in the experimental car.[154] NHTSA frontal crash tests do not exceed 30 mph.

The Minicars RSV proved that not only is significantly greater crashworthiness attainable for passenger vehicles, one route to superior frontal crash performance lies in advanced front structure design. Some engineers are hoping to achieve frontal crashworthiness similar to the RSV with lighter and more advanced bumper designs. One device, an external airbag (or airbag bumper) was first developed and tested in the mid 1990's by Dr. Carl Clark, early airbag investigator and former NHTSA scientist.[155] The airbag bumper is designed to inflate ahead of a vehicle in anticipation of a crash (utilizing crash anticipation technology like radar-based systems described in this report). Initial airbag bumper prototypes have demonstrated crash energy absorption of 19%.[156]

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[154] *The minicars research safety vehicle program phase III: technical summary*, Ausherman, V.K., Khadilkar, A.V., Syson, S.R., Strother, C.E., Struble, D.E., DOT HS 7-01552, September, 1981

[155] *Car Crash Theory and Test of Airbag Bumper Systems*, Clark, C., Young, W., SAE Technical Paper Series 951056

[156] Ibid

Restraint

Seatbelt Use Reminders

The National Academy of Sciences issued a report in 2003 on technologies to increase seat belt use. The NAS concluded that "NHTSA should encourage industry to develop and deploy enhanced belt reminder systems in an expeditious time frame, and NHTSA should monitor the deployment."[157] The Academy recommends a multiyear study of $5 million annually to study the effectiveness of enhanced belt use reminders, such as the FordBeltMinder, introduced in model year 2000 vehicles, which has been shown to increase driver belt usage rates from 71% to 76%.[158]

Seatbelt Pretensioners and Retractors

Before a crash (or at the beginning of a crash before significant body motion), belt pretensioners reel the seatbelt to a specified load level. When an occupant's inertia forces him into the belt following a crash, a retractor pays out the belt after the load exerted on it exceeds a predetermined level.

Pretensioners may be either electromechanical, designed to moderately tighten the belt and optimally position an occupant before a crash, or pyrotechnic, designed to firmly restrain an occupant just after a crash has occurred. Mechanical pretensioners may be

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[157] *Buckling up: technologies to increase seat belt use*, Transportation Research Board, National Academy of Sciences, 2003, p. 88

[158] *Effectiveness of Ford's belt reminder system in increasing belt use*, Williams, A.F., Wells, J.K., Farmer, C.M., Injury Prevention, Vol. 8, 2002, pp. 293-296

activated by control systems that detect loss of control or evasive maneuvers. Pyrotechnic pretensioners are triggered by any crash or pre-crash detecting sensor.

NHTSA studies have shown that pretensioners and retractors are effective in reducing injury criteria for head and chest regions in NCAP testing. On average, pretensioners and retractors reduced head injury criterion (HIC) values by 232, chest deflection by 10.6 mm and chest acceleration by 6.6 g's.[159] Pretensioners can substantially improve occupant restraint if activated before a rollover by a roll sensor.

According to NHTSA, approximately 63% of MY 2002 vehicles were equipped with pretensioners and approximately 84% were equipped with retractors or some other type of load-limiting system.

Improved Three-Point Belts

A relatively minor change in seat belt geometry could significantly improve the performance of three-point belt restraint systems. By reversing the points of attachments for the shoulder belt (so that the belt travels from the outboard side of the waist to the inboard side of the shoulder), lateral restraint—in the inboard direction—is increased, at least for certain crash modes such as rollover.[160] This result is somewhat obvious. Conventional shoulder belts extend across the outboard side of the body, making lateral inboard motion relatively easy.

Three-point belts with reversed geometry may require additional restraint systems to prevent injurious belt-neck interactions. Supplier Autoliv, in a recently published

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[159] *NCAP test improvements with pretensioners and load limiters*, Walz, M., NHTSA technical report, DOT HS 809 562

[160] *Seat integrated 3 point belt with reversed geometry and an inboard torso side-supoprt airbag for improved protection in rollover*, Bostrom, O., Haland, Y., Soderstrom, P., presented at the 19th international conference on the enhanced safety of vehicles (ESV), June 2005

study, tested the effectiveness of reversed-geometry belts in conjunction with side support airbags (SSA) mounted on the inboard side of the seat. In a simulated rollover, the reversed geometry belt and SSA improved lateral restraint (compared to a conventional three-point belt) without inducing severe neck loads.[161]

Reversed geometry belts require another innovation as well—integrated seatbelts, in which the belts are anchored directly to the seat (as opposed to the vehicle body). Integrated belts provide superior fit—and thus energy management—by more effectively coupling the seat and occupant during a crash. Even without a reversed geometry, integrated belts offer a safety benefit compared to conventional belt designs because of this advantage.[162]

Four-Point Seat Belts

Three-point belts, standard in passenger vehicles, cause thoracic and abdominal injuries in motor vehicle crashes. These injuries are not observed in auto racing crashes, where drivers are restrained with four, five, or six point belts. In light of this discrepancy, passenger vehicle manufacturers are beginning to evaluate the efficacy of four point belt designs.

Compared to three-point belts, four-point belts increase the surface area of the harness and thus reduce the stress on the belt fabric and the occupant. This superior energy management can reduce torso injury in less sturdy occupants. "At the age of 65, your ability to withstand crash forces is about one-fifth what it was when you were 20

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[161] Ibid
[162] *Rolling Over on Safety: The Hidden Failures of Belts in Rollover Crashes*, Public Citizen, April 2004

because the chest bones deteriorate with age," notes Steve Rouhana, Ph.D., group leader of Ford's Safety Research and Development Department.[163]

Four point belts may also help improve passenger restraint in rollover crashes, which frequently result in partial or total occupant ejection. A 2004 Public Citizen study of seatbelt performance noted the shortcomings of seat belts in rollover crashes (17% of belted occupants are ejected in rollovers) as well as the superior restraint offered by four-point design.[164]

Despite the simplicity of the technology and its existence for many years in automotive racing, passenger vehicle manufacturers have yet to agree on the optimal deployment or ultimate benefits of the four-point belts. Mercedes is wary of any design that would hold the torso too tightly to the seatback, increasing the risk of whiplash.[165] Volvo envisions the four-point belts as a front seat only restraint, utilizing a loose fourth strap to maintain the proper occupant position in the event of an airbag deployment, not to distribute crash forces as a tightly pulled belt would. [166] Four-point belts may also face a problem of customer appeal, potentially being more cumbersome and difficult to buckle.

Seat Belt Materials

Another solution to mitigate seat belt injury is the use of more resilient seat belt webbing. Honeywell has developed a novel copolymer (Securus®) that exhibits improved elasticity when compared to traditional polyethylene terephthalate (PET)

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[163] "Volvo thinks if three are good, four are better," The Car Connection, www.thecarconnection.com
[164] *Rolling Over on Safety: The Hidden Failures of Belts in Rollover Crashes*, Public Citizen, April 2004
[165] "In Search of the Perfect Seat Belt," Tom Lankard, MSN Autos, http://autos.msn.com/advice/article.aspx?contentid=4019915&src=GBT
[166] Ibid

fibers—without sacrificing tensile strength. According to the developers, seat belts made from the Securus®, a combination of PET and polycaprolactone, elongate and absorb energy when loaded to the equivalent of approximately 400 pounds.[167] By absorbing some of the crash energy less force is transferred to the buckled occupant.

Constant force retractors (CFRs) are designed to accomplish a similar force reduction by paying out the belt at a defined load limit, usually 1,000 lbs. Securus®, on the other hand, becomes elastic at a lower load limit (400 lb) and can therefore cushion lighter passengers—including children and small women. A load-leveling mechanical CFR cannot adapt to heavier passengers either, unlike Securus® which will apply greater restraining force when needed, i.e., for a heavy adult male.[168]

Securus® still offers a safety benefit when compared to next-generation belt retractors in certain applications, says its manufacturer. New seat belt retractors are *digressive* force retractors, which are optimal for front seat occupants (as less restraint is necessary when passengers reach the airbag). In the rear seat however, an increasing amount of resistance is preferable, according to Mike Moore of Key Safety Systems, Director of Seat Belt Engineering for North America and Asia.[169] Key Safety Systems has designed a rear seat belt assembly employing the Securus® webbing and is currently working cooperatively with manufacturers. Moore estimates the advanced webbing will be offered in rear seat belts for MY 2008 or MY 2009 vehicles.[170]

Craig Task, Business Manager of Securus® fibers for Honeywell, claims that the new fibers present a noticeable improvement in crash tests and "have demonstrated a

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[167] *Securus tm Fiber: A Load Leveling Copolymer for Safer Seat Belts*, Levy, M., Phillips, C., Nagy, M., Honeywell Performance Fibres
[168] Ibid
[169] Telephone conversation with Michael Moore, Key Safety Systems, May 16, 2005
[170] Ibid

one- to two-star improvement toward the New Car Assessment Program (NCAP) five-star performance score in safety."[171] Independent testing has not verified these claims.

Inflatable Seat Belts

A number of suppliers and inventors have developed inflatable restraints intended to further improve the energy absorption and force distribution of belt restraints. BF Goodrich announced an inflatable seat belt design in 2000, though they have since abandoned the project. TRW has also patented an inflatable seat belt system.[172] Early inflatable cushions attached to seat belts were patented in 1980.[173]

A 1998 NHTSA study evaluating the effectiveness of inflatable tubular torso restraints (ITTRs) in rollover crashes found that inflatable belts offer superior restraint and impart lower tensile forces to the neck compared to the performance of a baseline 3-point belt in a simulated rollover crash.[174] Quantitatively, the inflatable belts reduced dummy excursion by 60 to 75 percent.[175] The study concludes that "occupant excursion can be reduced in rollover crashes with appropriate countermeasures, such as the ITTR."[176]

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[171] *Securus™ Fiber: The Next-Generation Safety-Belt Fiber: New Fiber Designed to Protect a Broader Range of Body Types*, News Release, Honeywell Performance Fibers, March 4, 2002
[172] Inflatable seat belt using MEMS device, US Patent 6,598,899, 2003
[173] Safety cusion attachable to belt-type restraints, US Patent 4,348,037
[174] *Evaluation of restraints effectiveness in simulated rollover conditions*, Rains, G., Elias, J., Mowry, G., presented at the 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), May 1998
[175] *Evaluation of restraints effectiveness in simulated rollover conditions*, Rains, G., Elias, J., Mowry, G., presented at the 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), May 1998
[176] Ibid

Side Window Laminated Glass

Laminated glass (like windshield glass) is being installed for side-windows in a small number of 2006 model year vehicles.[177] Historically, manufacturers chose to install lighter tempered glass in side windows. While laminated glass will reduce the risk of occupant ejection in a crash, it might frustrate occupant extraction after a crash because laminated glass must be sawed through (unlike tempered glass which shatters). Studies of the ejection-extraction tradeoff between have not been publicly reported.

<u>Seat Design</u>

Headrest Geometry and Active Headrests

Whiplash injuries, a consequence of poor seat design and head-neck restraint in rear crashes, cost the US $7 billion per year in insurance claims.[178] An extremely low-tech (and non-innovative) solution to lessen the incidence of whiplash injuries lies in proper positioning and headrest geometry. Of 165 model year 2006 seat designs tested by the Insurance Institute for Highway Safety, only 50% received a “good” rating for seat/head restraint geometry, indicating a significant potential for headrest geometry improvement within the fleet.[179]

Conventional headrests, though, are inherently limited in the amount of energy absorption, and thus injury prevention, offered. Active headrests are engineered to move closer to a passenger’s head, and then absorb energy, in the event of a crash. The first

[177] “Laminated glass adds security and cuts highway noise,” Anita Lienert, *Detroit News*, September 7, 2005
[178] *Injuries in auto accidents,* Insurance Research Council. 1999
[179] Rear crash protection vehicle ratings, IIHS website, http://www.iihs.org/ratings/

active headrests, offered in the 1997 Saab 9-5, were mechanically linked to a pressure-activated plate in the seat back. When inertial forces push an occupant into the seat, the seatback plate pivots the headrest against the occupant's head.

Newer designs feature an electromechanical system triggered by a crash sensor and actuated by an electromagnetic activation plate. A 2003 study showed a 43% reduction in neck injury claims rates for Saab, GM and Nissan models with active head restraints.[180]

Integrated Child Seats

A 2002 Public Citizen study of seat belts and child seats exposed the dangers of conventional three-point belts and child safety seats, especially for 4 to 8-year olds.[181] Children in this range are usually too small to be effectively restrained by three-point belts (engineered and sized for adults), and are unlikely to be properly positioned or restrained in a booster seat.[182] The study notes that ten times as many children under 5 were killed in crashes in 1997 (even though restrained with a seat belt, child seat or other device), than were killed by airbags during the entire period between 1993 and 1998.[183] While airbag/child incompatibility was the subject of much public outrage and government involvement, little progress has been made to improve the effectiveness of more conventional child restraints.

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[180] *Effects of head restraint and seat redesign on neck injury risk in rear-end crashes*, Farmer, C.M.; Wells, J.K.; and Lund, A.K, Traffic Injury and Prevention, 4: 83 – 90 (cited from IIHS website)
[181] *The forgotten child: the failure of motor vehicle manufacturers to protect 4- to 8-year-olds in crashes*, Public Citizen with C. Tab Turner and Susan Lister, April 2002
[182] Ibid
[183] Ibid

In conclusion, the Public Citizen study recommends the use of integrated child seats with five-point harnesses.[184] Integrated child seats are built into standard passenger vehicle seats and are accessed by folding down a portion of the rear seat, forming the child seat and revealing the harness. Besides being a permanent and more rigidly attached seat, integrated child seats offer superior crash protection and convenience, according to sources cited within the report.

Integrated child safety seats were developed in the 1990's and are offered by a number of manufacturers, including Volvo and Daimler-Chrysler.

Side Impact Airbags

Manufacturers currently employ three types of side impact airbags: torso bags, tubular bags, and side curtains. Torso bags are designed to protect adult torsos (and in some cases, hips) in moderate and severe side impacts. Tubular airbags (featured by BMW) and side curtain airbags inflate from the roof across the side windows to protect the head from impact with the side and side windows and to provide occupant ejection protection.

Recent side impact testing by IIHS highlights the importance of side impact airbags, especially those with head protection. Under test conditions simulating a mid-size SUV striking a small car perpendicularly at 31 mph, only two of 16 cars received an "acceptable" rating from the Institute, the only two equipped with optional side curtain

[184] Ibid

bags.[185] Without the optional protection both cars, the GM Cobalt and Toyota Corolla, were rated "poor."[186]

Lower Extremity Airbags

Six manufacturers (Audi, BMW, Chrysler, Kia, Lexus, Mercedes, Toyota) currently offer some type of lower extremity airbag system as a standard feature. These passive restraints are designed either to inflate directly into the knee or to inflate behind the padded knee bolster, which then presses against the occupants' legs. In both configurations lower leg airbags are intended to maintain a safe leg position and prevent the "submarining" of an occupant under the frontal airbag during a crash.

Curiously, though leg/knee airbags represent the newest application of airbag technology, manufacturers have been slow to publicize their deployment. To date, no studies evaluating the effectiveness of leg/knee airbags have been completed.

Control Systems

Electronic Stability Control

Electronic stability control coordinates a network of sensors that detect vehicle trajectory and driver input and provides stabilizing assist if the car begins to drift off course. ESC incorporates and improves upon anti-lock braking (ABS) and traction control systems (TCS) by aiding drivers in lateral skid or spinout (understeer and oversteer) and on slick and dangerous road surfaces. More than simply preventing wheel

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[185] *New results of side impact crash tests: 14 of 16 small cars are rated poor in test that simulates crash with SUV; none of the 16 is good;* IIHS press release, March 6, 2005
[186] Ibid

lock or spin, ESC helps drivers maintain control of their vehicles *on their intended path*. ESC processors can quickly adjust individual wheel speed and engine power in a response time and profile that no passenger vehicle operator can accomplish, reducing the chance that the driver will lose control while cornering, braking, swerving and avoiding obstacles. Within the limits of braking and throttle response, ESC can correct driver error and loss of control caused by weather or road surfaces.

While ESC is not standard across the fleet, it is increasingly offered in more makes and models.[187] The Alliance for Automobile Manufacturers claims that 42% of 2006 model year vehicles have electronic stability control installed as a standard feature, and a total of 63% of new vehicles offer ESC as either standard or optional equipment.[188] In fact, the plethora of ESC systems has encouraged rival automakers to employ a dictionary of acronyms for their proprietary systems. Major automakers use at least 10 different names for the same technology (DSC, VSP, PSM, VDC…etc.). The ESC Coalition, a joint effort by suppliers Bosch and Continental, has formed to inform consumers about the benefits of this active safety technology and decode industry jargon.

The benefits of ESC are already being observed. According to the 2004 preliminary results of a NHTSA report analyzing the effectiveness of ESC, passenger cars equipped with ESC are 35% less likely to be involved in single vehicle crashes and 30% less likely to be involved in fatal single vehicle accidents than cars without electronic stability control.[189] SUV's are 67% less likely to be involved in single vehicle crashes and 63% less likely to be involved in fatal single vehicle crashes according to this

[187] "ESC Rates Skyrocketing," *Ward's Auto World*, March 1, 2005
[188] "NHTSA's new leadership will face host of pending regulatory issues in 2006," *BNA Outlook 2006*, January 30, 2006
[189] *Preliminary Results Analyzing the Effectiveness of Electronic Stability Control (ESC) Systems*, Evaluation Note, DOT HS 809 790, September 2004.

study.[190] The Insurance Institute of Highway Safety estimates 7,000 fatalities could be prevented every year if ESC were standard equipment on all passenger vehicles.[191]

Yet even with this impressive track record, less than half of all vehicles manufactured in the US are equipped with ESC as a standard feature.[192] This is in part due to an uninformed public, an unwilling retail sales force, and NHTSA's slow pace. According to Adrian Lund, Chief Operating Officer of IIHS, between 5% to 10% of car buyers request ESC when it is an option, though as many as 75% responded that they were "probably interested" in it when the benefits of ESC were explained as part of a J.D. Power and Associates Survey.[193] Though ESC is slowly becoming standard[194] it is otherwise packaged with additional options and promoted with varying enthusiasm, depending on a dealer's need to sell vehicles and meet quotas or cash flow needs. Moreover, though ESC costs about $100 to install, the package or option price can exceed five times that value, presenting an even more difficult purchase option for a buyer unfamiliar with the effects and benefits of an unseen electronic control system.[195]

For its part, NHTSA is monitoring the performance of ESC-equipped vehicles (through their record in crash databases), and has been directed by the SAFETEA-LU statute to establish a rollover prevention rule "consistent with stability-enhancing technology." The law requires NHTSA to issue a proposed rule by October 1, 2006 and a final rule by April 1, 2009.

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[190] Ibid
[191] "Electronic stability control found effective," news release, IIHS, October 28, 2004
[192] *A little-known safety feature that could save your life*, ConsumerReports.org, April 2005
[193] Ibid
[194] "ESC Rates Skyrocketing," *Ward's Auto World*, March 1, 2005
[195] "Stability systems may boost suppliers," *Detroit News*, November 30, 2004

Gyroscopic Roll Sensing

Gyroscopic roll sensing is the latest evolution of active safety technology in the family of ABS, TCS and ESC. Featured in the Volvo XC-90 SUV and some late model Ford Explorers, a roll stability control (RSC) system utilizes a dedicated gyroscope to monitor body roll. When the dynamics of the vehicle suggest a rollover is likely, the RSC program counteracts by adjusting brake torque and throttle application to reduce corning motion and the resultant roll moment. In a sense, the RSC system activates the underlying ESC (which in turn incorporates ABS and TCS) when roll sensors detect an unstable roll condition. Rollover sensors can also activate seat belt pretensioners, helping to restrain an occupant in the event the vehicle actually tips. Preventing rollover is a significant safety concern as over one-third of all motor vehicle occupant fatalities occur in rollover accidents.

Electronic Brake Assist

In the event of extreme braking, or when a pre-crash sensor detects an imminent crash, electronic brake assist reinforces manual pedal inputs and assure that maximum braking force is applied. In the case of an evasive maneuver, the master cylinder can be primed to ready the brake assembly to deliver maximum braking force. Continental Automotive Systems claims that brake assist can reduce the stopping distance of a vehicle traveling at 100 km/h by 33 meters.[196]

[196] Brake assist systems, http://www.conti-online.com/generator/www/de/en/cas/cas/themes/products/actuation/brake_assistents_en.html

Extra-vehicular Object Detection

A number of suppliers have developed short range radar systems capable of object detection at medium and close range. Depending on the specific orientation and systems integration, radar can be used to monitor a driver's blind spot, control speed, and anticipate accidents. Simple radar warning systems are available from large truck suppliers such as Delphi and Eaton. According to manufacturer's product specifications, the Eaton EVT-300 processes data from two antennae and the vehicle's engine to determine range, velocity and azimuth on up to 20 objects at a range of 350 feet. Car supplier Valeo is currently developing a blind spot detection system for a North American auto maker, expected to be in MY 2006 vehicles.[197]

In more sophisticated deployments, short range radar is integrated with a vehicle's throttle and braking systems in technology known as adaptive or active cruise control. The radar sensors allow the vehicle to automatically maintain a driver-determined following distance—instead of simply a steady speed. Adaptive cruise control may present a significant safety benefit in commercial trucks, which are especially dangerous when a tired operator engages a conventional cruise control system. Senator Frank Lautenberg recently wrote to Transportation Secretary Norman Mineta, requesting information on the steps taken by NHTSA and the Federal Motor Carrier Safety Administration (FMCSA) to investigate innovative vehicle technologies like adaptive cruise control that might mitigate some of the hazards posed by commercial trucks and tired truckers.[198]

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[197] *Valeo Raytheon Systems wins first Blind Spot Detection system contract*, Press release, Valeo Raytheon Systems, May 3, 2004

[198] Letter from Sen. Lautenberg to Secretary Mineta, December 7, 2005

In even more advanced configurations, radar systems are being designed by Bosch and others as part of a pre-crash sensing technology that can anticipate a crash and in the fractions of a second before impact communicate with other accident mitigation devices.[199] This system can optimize/trigger airbag deployment (according to accident severity and passenger type), actuate belt pretensioners, or apply brakes.

Lane Departure and Lane Keeping

Supplier Valeo SA has developed an optical lane-departure warning system that monitors lane markers and alerts the driver if the vehicle veers outside the lane of travel prior to a lane-change signal being activated. The system is offered for the first time as standard equipment on the 2005 Infinity FX45 sport wagon.

Toyota[200] and Honda[201] offer a similar warning system on vehicles sold only in Japan. Ford, GM and DaimlerChrysler have begun testing their own versions of lane-departure warning systems.[202]

Lane detection monitors can be integrated with steering systems to augment drivers' input and maintain the lane of travel. Toyota offers such a lane keeping system that is active only when adaptive cruise control is enabled.

[199] Bosch precrash sensorics, http://www.bosch.com/content/language2/html/2323.htm
[200] "Lane –change warnings come to US," *Automotive News*, November 1, 2004
[201] "Safety first," *Autotmotive Industries,* September 2004
[202] "Lane –change warnings come to US," *Automotive News*, November 1, 2004

Sensors

Weight and Size Passenger Detection

As discussed previously, advanced airbags require some type of occupant detection system to communicate location, size and weight information in order to vary inflation behavior. Multiple types of occupant detection systems are being developed by suppliers, including linear variable differential transformer (LVDT) weight sensors,[203] piezoelectric weight sensors, bladder-type weight sensors, ultrasonic sensors, infrared imaging, and optical cameras.[204]

GM combines weight detection with size detection, based on the seat position, in the 2006 Buick Lucerne. The system communicates how far the seat is from the dashboard and can vary the inflation volume and geometry of the passenger-side airbag.[205] Ford will also introduce a seat-based size detection system on some MY 2006 vehicles.[206]

Driver Alertness Monitoring

Siemens VDO manufactures an optical driver-alertness monitor that can identify signs of drowsiness or loss of focus by detecting a driver's visual path and blink pattern.[207] The system can function in place of the lane-change signal as part of an integrated lane-departure monitor (i.e., if the driver appears alert and focused on the road,

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[203] "Advanced Weight Sensing (AWS II), product specification sheet, Siemens VDO Automotive
[204] "New sensors mean safer airbags," Automotive News, November 1, 2004
[205] "The evolution of front airbags," Tara Mello, Edmunds.com, http://www.edmunds.com/ownership/safety/articles/45863/article.html
[206] Ibid
[207] Lane departure warning system with optional driver alertness detection, Siemens VDO Automotive, http://www.siemensvdo.com/default.aspx?menu=assistent

no lane-departure warning is issued when the vehicle drifts beyond lane markers), or can serve as a stand-alone alertness monitor.[208]

Lane-departure and driver-alertness monitoring offers the capability to significantly reduce the frequency of motor vehicle crashes (industry estimates put the number of US crashes involving lane-change error at 410,000 annually).[209] However, a more fundamental approach to the problem at hand—driver distraction—is called for as well.

Ironically, the promotional video used by Valeo to demonstrate its high-tech lane-departure warning system shows a driver becoming distracted while operating a high-tech keypad information panel in the center console.[210] One has to question the relationship this video presumes: ever more distracting driving environments will create the need for ever-more advanced driver-distraction countermeasures. On the contrary, the high frequency of distraction-induced crashes in the US may imply a need to *lessen* the auxiliary distractions within the driving environment, by simplifying controls and emphasizing the primary driving function. Some combination of both approaches—technological warning systems and a less distracting environment—may be the optimal solution.

Global Positioning System (GPS)

The two most commonly available automotive applications of GPS technology are interactive navigation systems and GM's OnStar ® telematics service. GPS

[208] Ibid
[209] "Lane –change warnings come to US," Automotive News, November 1, 2004
[210] Lane departure warning system with optional driver alertness detection, Siemens VDO Automotive, http://www.siemensvdo.com/default.aspx?menu=assistent

navigation systems, widely available in luxury cars, graphically depict real-time vehicle positioning data over a road map. The result is a video game-like representation of the vehicle traveling along its route, commonly displayed on a liquid crystal display (LCD) screen in the center console. GPS navigation systems can perform a number of trip-planning and directional services, from calculating the shortest route to a destination to locating service stations and restaurants.

GPS navigation, in its current applications, is of questionable safety benefit. Though GPS navigation may replace printed maps it is unclear that the input and operation of such devices while driving is a less distracting means of navigation. However, if the GPS signal were enhanced it could be employed in a variety of cooperative safety systems, including pre-crash sensing, adaptive cruise control, lane-departure warning, lane guidance, curve speed warning, pedestrian crossing warning and stop sign warning, as noted by Nissan in their response to a NHTSA request for comments on the subject of next generation GPS for automotive safety.[211] While some of these applications appear to be an inappropriately complex use of GPS (pre-crash sensing, for one), others are perhaps more efficient than alternative schemes (such as radar-based adaptive cruise control).[212]

Furthermore, when GPS is coupled with a traditional communication network—as featured in GM's OnStar® service—the technology can function in an important safety capacity. OnStar® combines GPS and cellular communication in a comprehensive service that can remotely unlock doors, locate a stolen vehicle, and most significantly, automatically notify emergency services in the event of crash. With the inclusion of

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[211] Response to Request for Comments by Nissan North America, "Civilian Use of, and Requirements for, the Next Generation of GPS for Automotive Safety," NHTSA-2005-20936-7, May 31, 2005
[212] Ibid

advanced sensors, systems such as OnStar® will not only be able to notify emergency responders a crash has taken place, but also communicate crash-specific details such as severity and passenger type. GM has scheduled OnStar to become standard on all MY 2008 vehicles, though a fee-based subscription is required after one year of purchase.[213]

GPS locating systems such as OnStar® are not without controversy, and have caused some to worry about privacy invasions. Privacy issues are addressed in more detail for electronic data recorders, discussed below.

Event Data Recorders

On-board electronic data recorders (EDRs) are a necessary tool of the aviation industry, where they are commonly referred to as "black boxes." EDRs are also becoming a common, though less well known, feature of new cars and trucks. For instance, GM installs EDRs on every new vehicle, and has done so since 2000.[214]

First developed in the 1970s as a post-crash data recorder to aid safety engineers in airbag deign, EDRs have since evolved to record pre-crash data as well.[215] In addition to providing invaluable data (and inexpensive, compared to manual crash investigations) for post-crash researchers, EDRs can communicate with telematic services like OnStar® to provide detailed crash information immediately following the event.

NHTSA has proposed standardizing the data stored by EDRs for manufacturers who choose to install them.[216] Even though NHTSA is not proposing mandatory installation of EDR devices, public opposition (on privacy grounds) to the government's

[213] Response to Request for Comments by OnStar "Civilian Use of, and Requirements for, the Next Generation of GPS for Automotive Safety," NHTSA-2005-20936-3, May 19, 2005
[214] "Racing pushes technology to forefront," Automotive News, November 15, 2004
[215] Ibid
[216] Notice of Proposed Rulemaking, NHTSA-2004-18029, 49 CFR Part 563

endorsement of the technology has peppered the NHTSA docket.[217] However, privacy concerns can be addressed with protective laws guarding against possible misuse of EDR data. Additionally, NHTSA has a long history of protecting sensitive information, such as is contained in national databases of fatal and non-fatal traffic accidents.

Biometrics

Biometric technology has been adapted to automotive applications in fingerprint ignition systems. One commercially available model prevents the car from being started without a registered fingerprint scan. The scanner can store up to 100 registered fingerprints.[218]

While the intent of biometric ignition locks is to prevent unauthorized drivers from operating the vehicle, the ability to know exactly who is in the driver's seat offers potential safety benefits. A single biometric scan could provide the equivalent function of size and weight sensors, provided the driver is registered. (If the driver's fingerprint weren't registered he couldn't start the car anyway.) The information is then communicated to the seat, mirrors and steering wheel, which adjust position, and the airbag, which anticipates the size and weight of the occupant. A biometric scanner could not, however, determine the location of the driver in the seat or assess an out of position condition.

Biometric locks may present some unusual drawbacks. Car thieves in Malaysia, undaunted by a biometric ignition lock on a Mercedes S-class, kidnapped a driver to start

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[217] NHTSA Docket 2004-18029
[218] SecuOn Auto, product specifications, Raviraj Technologies, http://www.ravirajtech.com/fingerprint_car_lock_immobilizer_alarm_india.html

his car and then chopped off his index finger with a machete to fashion a more portable key.[219]

The viability of a biometric blood-alcohol detector is also being researched.[220] Such a device would function as a noninvasive ignition interlock and prevent drivers from starting a vehicle if their blood alcohol content (BAC) exceeds the legal limit.

Market Availability of Auto Safety Innovations

Table 3. Market Availability of Auto Safety Innovations

Tier 1: Commercially Available	*Tier 2: Emerging Technologies*	*Tier 3: R&D*
Improved footwell structure	Hydrophobic glass	Reversed belt geometry
Pop-up hood	Four-point belts	ITTR
Pedestrian-friendly front structure	Occupant size detection	External airbags
Seat belt pretensioners	Driver alertness monitor	GPS guidance
Seat belt retractors	Biometric locks	GPS lane warning
Integrated seat belt	Elastic seat belt webbing	Biometric BAC monitor
Integrated child safety seat		All-weather headlights
Side impact airbag		
Lower extremity airbag		
Electronic stability control		
Roll stability control		
Occupant weight detection		
Seat position size detection		
Crash anticipation		
Electronic data recorders		
Active headrests		
Blind spot warning		
Lane departure/Lane Keeping		
Strong roof structure		
Adaptive cruise control		
Adaptive headlights		
Brake assist		
Head-up display		
Lower extremity airbags		
Seat belt use reminders		

[219] "Malaysia car thieves steal finger," Jonathan Kent, BBC News, March 31, 2005
[220] "Wilson announces Justice funds for law enforcement alcohol screening technology," press release from Congresswoman Heather Wilson, January 12, 2005

Auto Safety Technology Discussion

Next Generation Safety Advances are Integrative

The previous review of auto safety innovations forecasts a changing technological landscape with a new emphasis on dynamic response and integrated systems. Accordingly, the greatest advances in auto safety in the 5-10 year horizon will be due to the integration of passive and active safety technology.

All actors in the auto safety arena—government, manufacturers, suppliers, insurance companies, consumer groups—should concentrate less on the distinction between technology that avoids a crash and technology that mitigates the effects of a crash. In fact, automotive technology will soon be able to *anticipate* an inevitable crash, tailor the crash protection in response, and notify emergency services.

A synergistic integration has the potential to deliver more lifesaving benefits than the sum of the component parts. Consider the following hypothetical scenario: a vehicle begins to lose control around a slippery turn. A lane-departure warning alerts the driver who initiates an evasive maneuver. The ESC system senses the evasive maneuver and actuates TSC and ABS systems to help the driver maintain the direction of travel. A mechanical pretensioner tightens seatbelts. The driver is able to avoid an oncoming car but not a guardrail. The collision is anticipated by a pre-crash sensor, which activates brake-assist, fires pyrotechnic belt pretensioners and triggers advanced airbags which know how large and heavy the front seat occupants are by communicating with size and weight sensors. After impact, digressive force retractors prevent belt-induced injury to the front occupants.

As a result of the integrated safety systems, a potentially more dangerous collision with an oncoming car has been avoided, and the collision that does occur is at a lower speed due to the electronically-assisted braking. Airbag deployment is optimized by pre-crash sensing and occupant size and weight detection.

The implications of such a holistic approach to auto safety extend to the archetypal Haddon matrix. Developed by the first NHTSA administrator, Dr. William Haddon, the matrix provides a template for categorizing the phases and factors relevant to auto safety. The Haddon matrix is still regarded as a paradigm by NHTSA, industry, and consumer groups. Table 4 illustrates the Haddon matrix, crash factors, and corresponding safety technologies.

Table 4				
	Factors			
		Human	**Vehicle**	**Environment**
Phases	**Pre-Crash**	Distraction, Alcohol, Steering, Braking	RSC, TSC, ABS, Lane-departure, Mechanical pretensioners, Occupant detection	Road condition, weather
	Crash	Seat belt use	Airbag, Pyrotechnic pretensioners, Seat belts, Structure	Location, roadway objects
	Post-Crash	Alert emergency responders	Fire suppression, EDR, OnStar	Ambulance, hospital

Table 4. Haddon Matrix

Comparing the scenario described above to the Haddon matrix, it appears a new crash phase—crash anticipation—has been carved out between the pre-crash and crash phases. Based on this observation, a revised Haddon matrix is presented in table 5.

Table 5				
	Factors			
		Human	**Vehicle**	**Environment**
Phases	**Pre-Crash**	Distraction, Alcohol, Steering, Braking	RSC,ESC, Lane-departure, Mechanical pretensioners, Occupant detection	Road condition, Weather
	Crash-Anticipation	*Braking*	*Pre-crash sensing, brake-assist*	*Roadway objects*
	Crash	Seat belt use	Airbag, pyrotechnic pretensioners, Seat belts, Structure	Roadway objects, Location
	Post-Crash	Alert emergency responders	Fire suppression, EDR, OnStar	Ambulance, hospital

Table 5. Haddon Matrix (Revised)

NHTSA is Not Technology Forcing

The auto safety technologies being researched or developed by manufacturers, suppliers, inventors and entrepreneurs—that NHTSA has not anticipated—are evidence of the slow governmental response to innovation. Causes for this lag are structural and political.

As exemplified earlier in the discussion of NHTSA's role in advanced airbag rulemaking, agency attempts to gauge technological potential have been limited to information requests sent to major manufacturers. The direction of these information requests is curious in light of the fact that many modern auto safety technologies are developed at the supplier level and then applied by manufacturers (or collaboratively developed by suppliers and manufacturers). If NHTSA wanted to fully understand the domain of technological knowledge encompassing auto safety they would solicit suppliers as well.

Additionally, the gap between laboratory research and on-road performance data hamstrings NHTSA's ability to monitor the effectiveness of emerging technology that consumers purchase as optional equipment or devices that are offered only on luxury models. NHTSA is often late to mandate life-saving technologies. Such is the case with Electronic Stability Control, whose safety potential has already been documented in numerous and significant ways by independent studies and NHTSA's own reports. Moreover, NHTSA has acted in ways totally ignorant of the industry's technological potential, such as during the 2000 advanced airbag rulemaking, when it went against decades of airbag research by issuing a standard that rolled back test speeds and required decidedly un-advanced airbag systems.

The National Highway Traffic Safety Administration does not issue technology forcing standards. At most, NHTSA's mandates schedule the diffusion of well-established technology. The agency must improve its data collection, crash investigation, and research programs in order to more swiftly and proactively respond to motor vehicle safety needs in light of emerging technology.

NCAP Must Address Active Safety

The New Car Assessment Program, which rates vehicles' crashworthiness on a one to five-star scale, serves a vital public safety function as an information source to consumers and an incentive program for manufacturers. Federal Motor Vehicle Safety Standards set a required minimum level of safety, but NCAP ratings encourage the industry to go further. As the importance of active and passive safety systems integration increases, NHTSA should adapt NCAP appropriately.

Currently, NCAP tests evaluate crashworthiness exclusively. Deficiencies in the test procedures and ratings structure have already been reported by the General

Accounting Office, including the inability to evaluate vehicle-to-vehicle compatibility, the compression of vehicle ratings in the four and five-star range, and the erosion of the NCAP test incentive as NHTSA increases the speeds of FMVSS crash standards.[221]

In addition to fixing these problems, the program should also develop some type of analysis and ratings for active safety systems. The purpose and benefits of an active safety component to NCAP are numerous. First, different active safety systems with the same name may perform quite differently. A consumer information program that can differentiate and comment on the effectiveness of the various types of pre-crash sensing, brake-assist and electronic stability control will aid car buyers to make knowledgeable purchases and encourage the proliferation of the most valuable technologies. In addition, NCAP tests can be designed to evaluate the integration of active and passive safety features (say, in a combination of an evasive maneuver and crash) to provide a more realistic and total analysis of the vehicle's overall safety performance. As part of its upcoming rollover prevention rulemaking (required by SAFETEA-LU), NHTSA will be forced to consider these benefits anyway, as the statute calls for a new rule that establishes "performance criteria to reduce rollovers consistent with stability-enhancing technology."

According to comments at the 2005 conference on the Enhanced Safety of Vehicles (ESV) by Adrian Hobbs, Secretary General of the European NCAP program, there is a role for NCAP to play in active safety, though applying any test to measure the effectiveness of a device such as ESC is complicated. Foremost, the test needs to consider whether it will encourage driving at the limit of ESC or rather an early ESC intervention. If an early ESC intervention is preferable for ratings purposes, will

[221] *Opportunities exist to enhance NHTSA's New Car Assessment Program*, GAO, April 2005

consumers agree?   Also, how will manufacturers employ the use of an on-off control—and which position will most drivers default to?

Notwithstanding the difficulties of tailoring a successful active safety NCAP component, the EuroNCAP chief believes it is a priority. At the very least, much more work needs to be done. "There is a dearth of primary safety data worldwide," says Hobbs.[222]

Government Procurement

Proving the effectiveness of auto safety technology can be a significant hurdle in the development cycle, and the lack of good data can slow the introduction or standardization of life-saving innovations. Without a track record of success, manufacturers and regulators are hesitant to promote specific features. Experimental research can go only so far, and in the end is dependent on real-world data to corroborate findings. Active safety technology presents a particularly vexing problem of validity as discussed in the previous section.

In addition to testing concerns, the pace of technological diffusion from an optional product to standard equipment will be slow if the domestic fleet is used as a laboratory, considering that new cars and trucks make up less than ten percent of on-road vehicles. The low frequency of applicable cases studies (crashes involving vehicles with new safety technology) will be confounded by sampling errors inherent in national crash statistics models. These crash statistics models rely on probability samples taken from

[222] Comments of Adrian Hobbs, Secretary General of EuroNCAP, at the 19th annual international conference on the Enhanced Safety of Vehicles, June 8, 2005. Primary safety = active safety

police reports, and are part of the National Automotive Sampling System (NASS). Unlike NHTSA's database of fatal crashes—which is a total record of every fatal crash event—NASS samples a small portion of the millions of non-fatal traffic police accident reports to estimate an overall trend. While the NASS system is a useful tool for tracking general crash trends, it is an inappropriate means of evaluating emerging technology.

The error inherent in the NASS program illustrates just one shortcoming of attempting to substitute statistical sampling for closely monitored trials. For example, the standard error for crash estimates of 1,000 to 6,000 in the NASS-General Estimates System (NASS-GES) is 400 to 1,000. As table 6 shows, this means that the 95 % confidence interval for these estimates can be unhelpfully wide.

Crash Estimate	Crash Standard Error	95 % Confidence Interval
1,000	400	200 – 1800
5,000	900	3,200 – 6,800
6,000	1,000	4,000 – 8,000

Table 6: Crash sampling estimates and errors. Data adapted from Appendix C: GES Technical Notes, *Traffic Safety Facts 2004*, NHTSA

Accordingly, assessments of technological effectiveness can be frustrated by imprecise statistical data for features that lack widespread market penetration and thus are involved in fewer crashes. This problem is partly to blame for NHTSA's slow pace in ESC evaluation, even though ESC has been commercially available since 1995.[223] While NHTSA has offered a preliminary report on the effectiveness of the technology, the agency counsels that "We will feel more confident about the overall effectiveness of ESC when we have enough data on a more representative cross-section of the fleet including

[223] *Current Analysis of the Accident Statistics: Mercedes Passenger Cars Get Into Fewer Accidents*, Mercedes Benz, November 26, 2002

non-luxury vehicles and a wider variety of manufacturers. That is likely to take at least another year or two."[224]

To more swiftly and accurately evaluate the real-world performance of auto safety innovations, a dedicated fleet of vehicles, equipped with new features, needs to be put on the road and monitored. A cooperative program between the General Services Administration (GSA), purchaser of 60,000 civilian vehicles per year, and NHTSA, could accomplish such a task. The error inherent in extrapolating crash trends from an experimental fleet of vehicles will be much smaller than working backwards from NASS samples. Moreover, equipping procured vehicles with electronic data recorders would add a wealth of crash-related data not available from police accident reports.

GSA and NHTSA have worked together before, purchasing 5,000 airbag-equipped Ford Tempos in 1984, years before the airbag was a mandatory feature in cars. Results from this fleet: 100 crashes, 1 death (in a collision with a heavy truck), verified the on-road safety benefit of airbags and bolstered the argument that they be standard for all passenger vehicles.[225] A similar program between NHTSA and state governments or the Department of Defense could be envisioned as well.

The procurement process is not perfect, however, and is tailored to large producers. Gerald Carmen, former GSA Administrator, noted at a procurement conference in 1988 that, "What we miss in the procurement process is the middle-sized vendor, the middle-sized manufacturer, the people who are really innovative and creative,

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[224] *Preliminary Results Analyzing the Effectiveness of Electronic Stability Control (ESC) Systems*, Evaluation Note, DOT HS 809 790, September 2004.

[225] Remarks of Gerald Carmen, former GSA Administrator, from the Proceedings of a National Conference on the Uses of Government Procurement Leverage to Benefit Taxpayers, Consumers and the Environment, May 23-24, Washington DC , sponsored by the Center for Study of Responsive Law, 1988

the people who probably designed the airbag, the safety glass and the high level tail-light."[226]

Even if government procurement cannot stimulate the most inventive agents, it can still provide an invaluable source of data for emerging auto safety technologies. The General Services Administration, at the behest of NHTSA, should be actively purchasing vehicles with optional safety equipment—listed in table 3 under the heading *commercially available*. These experimental safety fleets should be monitored by NHTSA and the resultant data analyzed in the overall context of a performance assessment of market-available auto safety innovations.

The Auto Insurers

According to Keith Bradsher, former Detroit bureau chief for the *New York Times*, the manner by which insurers price liability coverage has been a "terrible lost opportunity over the last quarter of a century," from a public safety perspective.[227] Insurance companies for the most part have resisted adjusting liability rates by make and model to reflect potential liabilities, a practice that has disguised costly and dangerous externalities.

In the 1970's, this practice tended to favor the less affluent, who still owned the "older land barges of the used-car market."[228] Adjusting liability rates by model would have meant "raising premiums for the less affluent and lowering them for the affluent,"

[226] Ibid
[227] *High and Mighty: The Dangerous Rise of the SUV*, Keith Bradsher, Public Affairs publishers, 2002, p. 218
[228] Ibid, p. 211

who were purchasing new, smaller cars.[229] By the 1990's, however, affluent consumers tended to buy larger vehicles, especially SUVs.

The insurance industry's own risk assessment arms, the Insurance Institute for Highway Safety and the Highway Loss Data Institute, began to document the increasing damage inflicted by SUVs in the last decade. In 1994, HLDI completed a study which found that property damage from accidents involving large SUVs were 72 percent greater than for average cars, even controlling for other factors.[230] Yet insurers remained generally indifferent to SUV loss or car loss. Insurance premiums remained relatively steady from one model to the next, as the industry feared that higher SUV rates would anger affluent owners, who were typically multiple-policy purchasers.

Bradsher reports that Progressive, then a mid-size insurance company insuring drivers with the worst records, began adjusting by model in the late 80's, but not until 1997 did a major insurer (Farmers) begin linking premium rates to model type.[231] Farmers rate adjusting experiment was short lived, and other major insurers who followed the example did so on a limited basis—with rate differentials that did not match actual variations in claims. As of 2002, Nationwide varied premiums by plus or minus 10 percent, and Allstate varied by plus or minus 15 percent, not even close to the 72 percent difference that the 1994 HLDI study found.[232]

State Farm continues to resist any adjustment by model. Bradsher reports that a State Farm actuary believes SUVs save money for insurers by killing other motorists who

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[229] Ibid, p. 218
[230] Ibid, p. 212
[231] Ibid, p. 214
[232] Ibid, p. 219

might live through a crash with a smaller vehicle. "Serious injuries produce larger legal settlements than deaths."[233]

But public sentiment appears to be on the side of rate adjustment, and those familiar with the industry say that insurers are calculating premiums more specifically than in the past. However, the low coverage limits for auto insurance policies reduce insurers' incentives to adjust premiums in a manner that ever reflects the total cost of operating the vehicle. For instance, while NHTSA estimates that the economic cost of severe injuries due to motor vehicle crashes is more than $1 million per patient,[234] medical, liability, and uninsured motorist payments are typically capped at $100,000 or $300,000. Because auto insurers are not liable for the true extent of economic loss from motor vehicle crashes, they are not encouraged to convey these liabilities in the form of representatively calculated premiums. Carl Nash, Ph.D., former NHTSA executive and currently Adjunct Professor of Engineering at the National Crash Analysis Center at George Washington University, proposes a supplemental insurance scheme to cover these additional costs.

Dr. Nash's proposal, which he calls Catastrophic Automotive Crash Injury Insurance (CACII), would have high deductibles (at least $25,000) and high payment limits (at least $10 million), and would reduce payments for drivers proven to have been operating under the influence of alcohol and occupants not using seat belts.[235] Nash estimates the cost for the first 10 years of CACII coverage at the time a new vehicle is

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[233] Ibid, p. 215

[234] *The economic impact of motor vehicle crashes 2000*, National Highway Traffic Safety Administration, 2000, p. 62

[235] *A market approach to motor vehicle safety…that also addresses tort reform*, Nash, C.E., 2005, available from author

sold would be “no more than $500, including profit, for a safe vehicle.”[236] Nash defines a safe vehicle as one that weighs at least 2,800 pounds, has an effective belt use reminder, a strong roof, electronic stability control, and seat belt and side curtain airbags triggered by rollover sensors. CACII rates for older and more dangerous vehicles would be adjusted to reflect their safety performance record. The CACII plan attempts to conceptualize the principle that, “Insurance premiums should, in fact, reflect the actual crash injury cost experience and expectation for a vehicle.”[237]

In addition to catastrophic insurance coverage, auto insurers might investigate the possibility of incentives or premium adjustments for a host of emerging auto safety technologies (listed in table 3). Insurers offered just such a discount when airbags first became commercially available, but resist doing so today.

The industry can also provide NHTSA with data to help speed the identification of possible safety defects. According to a 2001 NHTSA study, insurance companies’ subrogation data and certain insurers’ claims databases could be used to serve as a type of early warning system for defective parts.[238]

Fundamentally, the auto insurance industry should not lose sight of its historical role in loss prevention[239] or its ethical duty to honestly assess motorists’ risks. Any effort by insurers to hide the dangers of particular vehicle models betrays a fiduciary responsibility to their policyholders.

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[236] Ibid
[237] Ibid
[238] *TREAD ACT Section 3(d) Insurance Study*, NHTSA, 2001
[239] *Loss prevention and the insurance function*, Nader, R., Suffolk University Law Review, Vol. XXI No. 3, 1987, pp. 679-689

Standards Setting and Harmonization

Before safety standards were issued by NHTSA, a patchwork of auto industry-sponsored technical standards, including those relating to safety, were written by professional societies, most importantly the Society of Automotive Engineers. In fact some of the original Federal Motor Vehicle Safety Standards were directly adapted from SAE technical standards, equating the first-ever federal safety standards with industry benchmarks.

Technical standards may serve three purposes: (1) to establish a minimum level of performance or quality, (2) to facilitate compatibility or reproducibility, and (3) to define the areas or methods of competition within an industry. As an issuer of safety standards, NHTSA operates almost solely with the first objective in mind. As an agent of industry,[240] SAE's goals are absorbed in the latter two functions.

The dichotomy of voluntary technical standards set by industry and imposed safety standards set by regulatory bodies is important to consider as the standardization process is subsumed within the all-encompassing sphere of globalization. As fewer global manufacturers wall off larger sectors of the economy and increase their geographic reach they aid their growth by establishing one common technical standard for component parts, assemblies and protocols. The process is known as harmonization.

Encouraged by large manufacturers, NHTSA has adopted a protocol for considering international vehicle standards. The rule concerning harmonization declares that NHTSA will focus its harmonization activities only on foreign vehicle safety

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[240] See chapter 4

standards that “require significantly higher levels of safety performance than the counterpart US standards.”[241]

Reality is more complicated, as in the case of headlights. European headlights are designed to output more light than American headlights and might be considered safer as a result. But European lights are also shaped in a pattern than directs most of the light toward the ground. Henry Jasny of Advocates for Auto Safety points out that, “This is fine in Europe where overhead highway signage is independently lit, however it is unsafe in the US where overhead signage is largely unlit signs with retroreflective tape that requires light from vehicle headlights in order to function properly and be seen by the driver.”[242]

The headlight example illustrates the difficulty and subtlety of comparing similar safety standards and underscores the need for safety advocates to be watchful of the process. The harmonization process is also considerably more involved than NHTSA’s own review and adoption of foreign standards. The goal of automotive harmonization is the global technical regulation (GTR), with which manufacturers the world over are supposed to comply, and which become the legal trade standard under World Trade Organization (WTO) rules. The first GTR, relating to door latches, was signed in November of 2005 in Geneva.[243]

The agreement that binds nations to the GTR was reached in 1998 at the United Nations and the body that considers their adoption is the World Forum for Harmonization of Vehicle Regulations (Working Party 29), a working party of the United Nations Economic Commission for Europe (UNECE). According to UN documents, WP.29

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[241] 49 CFR Part 553, NHTSA-98-3815
[242] Email from Henry Jasny, Advocates for Auto Safety, June 14, 2005
[243] “Global auto-safety standard OK’d,” Jayne O’Donnel, *USA Today*, November 16, 2004

regulations are intended to (1) improve vehicle safety, (2) protect the environment, (3) promote energy efficiency and (4) increase anti-theft performance.[244]

Unlike NHTSA, which informs the general public of any proposed rules and invites all comments, only registered parties may participate in WP.29 affairs. Non-governmental organizations, including consumer advocates, may participate so long as they are an NGO with consultative status to the United Nations Economic and Social Council (ECOSOC). NGO's without consultative status must be invited to participate by the UNECE secretariat or the concerned group's chairman.[245]

The bureaucracy and complexity involved in crafting a GTR causes some to worry that a harmonized standard will be immutable once passed. Joan Claybrook of Public Citizen is concerned that, "If a standard makes an improvement but doesn't go as far as we think it could, the likelihood it will be changed in the near future is zilch."[246]

Public Citizen notes that an array of laws (including the Administrative Procedure Act, the Freedom of Information Act, and the Government Sunshine Act) keep the US regulatory process "open", "consultative," and "democratic."[247] By contrast, harmonization proceedings typically lack transparency and participation from a "diversity of stakeholders."[248] Even if parties with a variety of interests are permitted to attend harmonization proceedings, the requirements of international travel are prohibitive for most academics, public interest groups and citizens.[249] Accordingly, most harmonization proceedings are dominated by industry, leading some to question the "appropriateness

[244] Frequently asked questions regarding WP.29, http://www.unece.org/trans/main/welcwp29.htm
[245] Ibid
[246] "US agrees to door-latch standard," Dee-Ann Durbin, *Associated Press,* November 16, 2004
[247] *Harmonization 2004 Guidebook*, Public Citizen
[248] Ibid
[249] Ibid

and legitimacy of relying on these institutions to set global policy, especially in sensitive consumer, environmental and worker-related areas."[250]

In specific regard to technological innovation, Henry Jasny foresees little overall effect from the harmonization process, though he notes that "if a technology had to be adopted internationally, manufacturers might be more wary about how they introduce new technology into production models."[251]

[250] Ibid
[251] Email from Henry Jasny, Advocates for Auto Safety, June 14, 2005

8. Technology to Improve Passenger Vehicle Fuel Efficiency

Technology Review, a publication of MIT, did not mince words in 2002 when it reported on the prospect of high-mileage passenger vehicles. "[I]f it chose to, Detroit could manufacture a 40-mpg SUV by the end of the decade."[252] The magazine details the viability of a gasoline internal combustion engine to power 46 mpg cars and 40 mpg SUVs, as reported in a 2001 study of proven fuel efficient technologies commissioned by the American Council for an Energy-Efficient Economy (ACEEE).[253]

The ACEEE study cited by *Technology Review* highlights similar fuel saving technologies investigated by the National Academies of Science in their 2002 report *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, and a more recent study by Argonne National Laboratory, *Examining the Potential for Voluntary Fuel Economy Standards in the United States and Canada*. These studies are thorough and expert evaluations and a comparison of them reveals many of the opportunities and pitfalls related to the improvement of passenger vehicle fuel economy by means of efficiency gains.

The NAS study evaluated technology that is currently known and available to manufacturers ('production intent') and technology that is beyond the research phase but still in development ('emerging technology'). NAS then categorized the technology according to its application in the engine, transmission, or vehicle system. The ANL study more closely analyzed weight reduction (investigating certain steel alloy and

[252] *Why not a 40-mpg SUV?*, Technology Review, November 2002
[253] *Technical Options for Improving the Fuel Economy of U.S. Cars and Light Trucks by 2010-2015*, DeCicco, J., An, F., Ross, M. American Council for an Energy Efficient Economy, April 2001

aluminum body structures) and electric control (specifying more electronic accessories such as electric pumps and throttle control).

ANL and ACEEE also evaluate the viability of direct injection engines (only mentioned by NAS as an R&D item of promise) and hybridization (which NAS evaluates separately from all other technology). Hydrogen fuel cells are considered not commercially viable in the near term by any study.

Regardless of the optimal engine/vehicle design, on one issue the scientific community agrees: the opportunity to increase the efficiency of passenger vehicles exists today—even with traditional gasoline internal combustion engines. Table 7 summarizes many of the creative and technologically innovative means engineers have at their disposal to increase car and truck efficiency.

Table 7. Market Availability of Fuel Efficiency Innovations

Tier 1: Commercially Available	*Tier 2: Emerging Technologies*	*Tier 3: R&D*
Engine Improvements		
Engine friction reduction	Intake valve throttling	Hydrogen internal combustion
Low-friction lubricants	Camless valve actuation	Hydrogen fuel cell
Multivalve overhead camshaft (2-V vs. 4-V)	Variable compression ratio	
Variable valve timing (VVT)	Gasoline direct injection (GDI)	
Variable valve lift and timing (VVLT)	Homogeneous Charge Compression Ignition (HCCI)	
Cylinder deactivation		
Engine accessory improvement		
Engine supercharging and downsizing		
Natural gas combustion engine		
Transmission Improvements		
6/7/8 speed automatic transmission	Automatic shift/manual transmission (AST/AMT)	
Continuously variable transmission (CVT)	Advanced CVT's – higher torque	
Automatic transmission w/ aggressive shift logic		
Vehicle Improvements		
Aerodynamic drag reduction	42-V electrical systems	
Improved rolling resistance	Integrated starter/generator (no idle)	
Materials weight reduction	Electric power steering	
Gasoline hybrid-electric vehicle	Electric pumps	
Diesel hybrid electric vehicle	Advanced materials weight reduction	
	Plug-in hybrid	

Consumer Demand and Corporate Offerings

The success of the Toyota Prius (which averages about 44 miles per gallon) proves American customers value fuel economy. Sales of the Prius in April 2005 were 196% higher compared to April of the previous year.[254] In fact, American carmakers are now rushing to license or develop their own hybrid drivetrains. Detroit must play catch-

[254] Toyota USA Reports April 2005 Best-Ever Sales Month, Press Release, Toyota Motor Corporation, May 3, 2005

up to the Japanese, who enjoy a competitive advantage in hybrid technology by at least one vehicle generation. Some domestic automakers now admit the error of their ways. "Do we wish we had them? Of course we do," bemoans GM's Bob Lutz.[255]

But the story of the Prius, and of Toyota's overall product development, is more complicated. While any Prius that Toyota sells improves their bottom line, Toyota is eyeing the Detroit-dominated large truck and SUV segment as the last hurdle in the race to overtake GM as the world's largest automaker. After waiting decades to join the fray, Toyota is finally game to challenge the Big Three in the large truck market. The large truck market includes such well-known models as the Dodge Ram, the Chevrolet Silverado and the Ford F-Series pickup, which is the best selling vehicle of any type, car or truck. Truck buyers are also notoriously loyal, much more so than car buyers, and much less willing to purchase a foreign vehicle for a traditionally American vehicle task, making Toyota's competition disadvantaged.

Yet the sales performance of Toyota trucks indicates the Big Three might have some worrying to do. Comparing the same sales periods (April 2004 and April 2005), Toyota sold 10,932 full-size Tundras,[256] a 21% increase, compared to a 4% increase for Dodge Rams, a 2% increase for Ford F-Series trucks and a 12% decrease for the Chevrolet Silverado. In the large SUV category, Toyota weathered a tough April 2005 at least as well or better than its American rivals, seeing a 10% sales decline for Sequoias, compared to a 9% drop for the Dodge Durango, 20% less Ford Expeditions and 36% less Chevy Tahoes. So in the same month that Toyota touted its record Prius sales, it sold almost an equal number of full size Tundras, in addition to 4,000 full-size Sequoias.

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[255] *The End of Detroit*, Micheline Maynard, Currency Doubleday, p. 286
[256] The Tundra is a new model and sales figures will not reflect a mature market, but they are useful to gauge consumer interest nonetheless.

	Sales April 2005	Sales April 2004	Change (%)
Toyota Prius	11,345	3,684	196.5
Full size pickup			
Toyota Tundra	10,932	8,672	33.9
Ford F series	71,367	70,166	1.7
Dodge Ram	35,986	33,284	-4
Chevrolet Silverado	55,075	60,554	-12.4
Full size SUV			
Toyota Seqouia	4,039	4,319	-12
Ford Expedition	9,460	11,831	-20
Dodge Durango*	8,626	9,104	-9
Chevrolet Tahoe	10,134	15,357	-36.5

Table 8. Compiled from Toyota, GM, Ford, Daimler-Chrysler sales data.
* Durango was initially a mid-size SUV but was redesigned and upsized for MY 05

Toyota has brightened its corporate image in the gleam of the socially responsible Prius, but this marketing and sales success belies the more cutthroat nature of the auto industry, which hungers for any available profit. Kevin Wilson, executive editor of *Automotive News*, commented in May 2005 that the Prius is "A free pass for Sequoias," and noted that, "Perspective requires one to look farther down the road than the bottom line on the latest quarterly sales report."[257]

Consider the math: the four-wheel drive Toyota Sequoia is rated 15 mpg in the city and 17 mpg on the highway by the EPA. Driving 12,000 miles in one year will burn 890 gallons of gasoline, about 450 gallons more than the legislated 27.5 mpg average for fleets of passenger cars. The extra 450 gallons burned will release an extra 8,775 lb of carbon dioxide compared to a car that averages 27.5 mpg. In order to absorb this much extra carbon dioxide one would need to plant at least two dozen sequoia trees.[258]

[257] "A free pass for Sequoias", Kevin Wilson, *Automotive News*, May 2, 2005
[258] Carbon dioxide sequestration is complicated and depends on many factors including tree type, size, age, soil composition and climate. A 1999 study estimated that a large (48 ft tall, 40 foot spread) tree provides a

Further, because the Toyota Sequoia is a 4,800 lb SUV, it has a higher propensity to rollover and is significantly more deadly than a lighter, smaller, and lower car in vehicle-to-vehicle crashes.[259]

By September 2005, hybrid vehicles (Toyota Prius and Lexus 400h) accounted for 7.3 percent of all of Toyota's sales, compared to 5.4 percent for the Tundra and Seqouia.[260] While this trend may be indicative of an overall slide in the popularity of large trucks, it's too early to discern a long term corporate strategy on behalf of Toyota, or any major automaker, to fully invest itself in fuel saving designs while moving away from the largest and most inefficient vehicles. Even Honda, historically an innovator of small and efficient vehicles, entered the pickup truck market for the first time ever in 2005 with the unconventional mid-size Ridgeline.[261]

On the opposite end of the spectrum lies perhaps the smallest and most forward-thinking car company, Hypercar Inc. The Hypercar concept was initiated by Amory Lovins's Rocky Mountain Institute to investigate the technological potential of building an efficient vehicle without compromising performance, comfort, or safety. In 1994, the Hypercar Center was founded to "place the concept in the public domain and share it conspicuously with some two dozen major car companies."[262] By putting the concept in the public domain, the Rocky Mountain Institute aimed to prevent private licensing. In

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net carbon dioxide benefit of 320 lbs/yr. *Tree guidelines for San Joaquin Valley Communities*, McPherson, E.G., Simpson, R.J., Peper, P.J., Xiao, Q., Western Center for Urban Forest Research, USDA Forest Service Pacific Southwest Research Station, 1999.

[259] Although the 2004 Sequoia received 5-star ratings in NHTSA frontal crash tests, its higher center of gravity, stiff frame construction, and heavy curb weight pose dangers to its occupants and other motorists. See *High and Mighty: The Dangerous Rise of the SUV*, Keith Bradsher, Public Affairs publishers, 2002

[260] "Toyota announces 2005 best-ever third quarter and September sales," news release, Toyota Motor Sales, October 3, 2005

[261] "Honda Ridgeline truck unveiled at 2005 North American International Auto Show," news release Honda Worldwide, January 10, 2005

[262] The Hypercar Concept, http://www.hypercar.com/

1999, Hypercar Inc., a for-profit company, was founded to develop the underlying technologies and "speed the industry's transition by exerting direct competitive pressure."[263]

The Hypercar vehicle concept relies on a low weight, low drag composite body, electronic control systems, and high efficiency powertrains (first hybrid-electric, eventually hydrogen fuel cell). Lovins follows quite a different paradigm than the major automakers, and sets lofty goals. According to the Hypercar website, Lovins hopes to achieve a "3 to 5-fold improvement in fuel economy, equal or better performance, safety, amenity and affordability, compared to today's vehicles."[264] While Amory Lovins preference for hydrogen propulsion may not be consistent with most other independent transportation researchers, his aim to build an ultra-light yet safe passenger vehicle is noteworthy for its inventiveness and its departure from the trends of major automakers.

Corporate Average Fuel Economy Standards (CAFE)

The corporate average fuel economy (CAFE) program, enacted in 1975, first stimulated manufacturers to improve the efficiency of vehicle designs using advanced technology, then helped to encourage the production of more light trucks (which are held to a lower standard than passenger cars), and has now actually stagnated the overall fuel economy of the passenger vehicle fleet. The EPA has observed that while vehicle weight and acceleration has increased over the past two decades, fuel economy has remained

[263] Ibid
[264] Ibid

relatively constant.[265] This reveals the automakers' general response to CAFE standards, which has been to increase their production of light trucks and focus their engine research on specific power improvement, not gas mileage gains. Overall, today's engines deliver much more power per unit displacement than those of 1981, but they do not go farther on a gallon of gas.

The original CAFE law established two fleet-wide fuel economy averages for manufacturers: one for cars, set by Congress, and one for light trucks, set by NHTSA. Congress set the car average at 27.5 mpg, to be phased in by 1985. NHTSA very slowly bumped up the light truck standard, starting at 17.2 mpg and leveling out for a time at 20.7 mpg in 1997.[266] For CAFE purposes, a light truck was originally defined as a truck or truck derivative with gross vehicle weight (a vehicle loaded to its maximum capacity) below 6,000 pounds, and was subsequently increased to include trucks with gross vehicle weights up to 8,500 pounds in 1978.[267] Because SUVs and minivans have truck characteristics (SUVs are built on truck frames and minivans have flat loading areas), manufacturers are able to classify these vehicles as light trucks.

When CAFE laws were written in 1975, only 20 percent of light duty vehicles sold were light trucks.[268] Most light trucks were true pickups and were owned by farmers,

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[265] *Light Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005*, EPA, Office of Transportation and Air Quality

[266] *Automobile and Light Truck Fuel Economy: Is CAFE up to Standards?*, Robert Bamberger, Congressional Research Service, September 16, 2002

[267] *High and Mighty: The Dangerous Rise of the SUV*, Keith Bradsher, Public Affairs publishers, 2002, p. 29

[268] *Light Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005*, EPA, Office of Transportation and Air Quality

businesses, and motorists with legitimate hauling needs. Few had gross vehicle weights over 8,500 pounds.[269]

In the three decades since the enactment of CAFE standards, automakers have exploded their production of light trucks and taken advantage of the 8,500 lb ceiling. Today light trucks comprise 50 percent of vehicle new sales.[270] Many are SUVs, designed as highway bound people-movers, not off-road trucks, and some are certified by manufacturers with gross vehicle weights just above 8,500 lb, escaping all fuel economy standards.[271]

Table 9 lists some popular four-wheel drive SUVs and their respective fuel-efficiency. Because current EPA tests exaggerate on-road fuel economy performance, the agency recommends multiplying the city test value by 0.9 and the highway test value by 0.78 to calculate the actual gas mileage achieved in those driving conditions. To average the city and highway values, it was assumed that the city value would account for 63 percent of the average, as the EPA reports that 63 percent of driving is done in the city.

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[269] *High and Mighty: The Dangerous Rise of the SUV*, Keith Bradsher, Public Affairs publishers, 2002, p. 28

[270] *Light Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005*, EPA, Office of Transportation and Air Quality

[271] *High and Mighty: The Dangerous Rise of the SUV*, Keith Bradsher, Public Affairs publishers, 2002, p. 29; *Automobile and Light Truck Fuel Economy: Is CAFE up to Standards?*, Robert Bamberger, Congressional Research Service, September 16, 2002

4WD, 2006 MY SUV	EPA City	EPA Highway	Adj. City	Adj. Highway	Average MPG
Hummer H1					8-11 (est.)
Hummer H2					8-11 (est.)
Jeep Grand Cherokee	12	15	10.8	11.7	11.1
Dodge Durango	12	15	10.8	11.7	11.1
Chevrolet Tahoe 1500	14	18	12.6	14.0	13.1
Ford Expedition	14	17	12.6	13.3	12.8
Ford Explorer	14	20	12.6	15.6	13.6
Toyota Sequoia	15	17	13.5	13.3	13.4

Table 9. Data from EPA, fueleconomy.gov. Hummer H1 and H2 exceed 8,500 lb GVWR and are not subject to EPA testing.

As the light truck fraction of new passenger vehicle sales grew during the 1990's, the average gas mileage of the entire fleet slumped. Today the combined fuel economy of cars and trucks is 24.6 mpg, just under the 24.7 mpg of new cars and trucks sold in 1982.[272] A higher mix of light trucks is more inefficient—and more unsafe, because of the added dangers SUVs pose in rollover and vehicle-to-vehicle crashes.[273]

From 1994 to 2000, Congress froze CAFE standards. Even though NHTSA was authorized to increase the light truck standard under the 1975 CAFE law, successive appropriations bills passed by the House and Senate in the late 1990's prohibited the agency from using any funds to issue fuel economy rules.[274] The ban on CAFE rules was finally lifted in 2000, when an agreement was reached to replace the prohibitive appropriations rider with a provision that authorized the National Academy of Sciences to study the issue and recommend appropriate fuel economy standards.[275]

In 2003, two years following the issuance of the NAS report (which did not recommend a specific fuel economy target), NHTSA raised the light truck standard to

[272] *Light Duty Automotive Technology and Fuel Economy Trends: 1975 Through 2005*, EPA, Office of Transportation and Air Quality
[273] *High and Mighty: The Dangerous Rise of the SUV*, Keith Bradsher, Public Affairs publishers, 2002
[274] *Automobile and Light Truck Fuel Economy: Is CAFE up to Standards?* Robert Bamberger, Congressional Research Service, September 16, 2002
[275] Ibid

22.2 mpg, to be phased in by model year 2007. In 2005, NHTSA again proposed raising the light truck standard, and the way light trucks are classified—defining 6 size classes. The editors of *Automotive News* were quick to criticize the new standard, which they claimed "doesn't go far enough," and called the plan's aggregate impact on light truck fuel economy (24 mpg by 2011) "hardly a stretch."[276] In light of the many technologies available to automakers to increase the fuel economy of their vehicles, and the calculation by ACEEE that SUVs alone could reach 40 mpg by 2010, this opinion seems quite reasonable.

CAFE's Impact on Technology and Safety

Enemies of fuel economy regulation have charged that CAFE rules encourage automakers to manufacture lighter vehicles that are necessarily more unsafe than heavier models and cause higher traffic fatality rates. In a November 14, 2005, op-ed published in the *Wall Street Journal*, Sam Kazman of the Competitive Enterprise Institute claimed that there is a "documented trade-off between between fuel economy and vehicle crashworthiness—larger, heavier cars get fewer miles per gallon, but also have lower death rates."[277] The *Journal's* editorial page asserted a similar relationship and cited Kazman's Competitive Enterprise Institute, opining that "higher fuel-efficiency standards for cars would cost lives."[278]

The *Journal* and Kazman both rely on the National Academy of Sciences CAFE report to support their claims. The NAS report, in turn, performed a literature review on the subject. Rather than conducting original research, a majority of the panel agreed with

[276] "Truck CAFE plan is weak; makers must beef it up," *Automotive News*, August 29, 2005
[277] "CAFE is bad for your health," Sam Kazman, *Wall Street Journal*, November 14, 2005
[278] "No blood for oil," Editorial, *Wall Street Journal*, September 14, 2005

the principal findings of a 1997 study by NHTSA's Charles Kahane.[279] The Kahane study claimed that a 100 lb mass reduction in cars and light trucks in 1993 would result in 250 additional fatalities.[280] The NAS panel then extrapolated this effect based on the fact that cars were 700 lbs heavier on average in 1976 and light trucks were 300 lbs heavier. The report then estimates this weight reduction resulted in an additional 2,000 fatalities in 1993 that would not have occurred if vehicle weights had remained at 1976 levels.[281]

This finding was so controversial that two members of the panel, David Greene and Maryann Keller, issued an eight page "Dissent on Safety Isssues" as an appendix to the report. Greene and Keller write that the conclusions of the majority in the chapters pertaining to CAFE's effect on safety "are overly simplistic and at least partially incorrect."[282] Fundamentally, Greene and Keller take issue with the majority's decision to estimate a 2,000 fatality increase based on the Kahane work. As Greene and Keller point out, even a National Research Council panel that reviewed Kahane's work found that:

> The NHTSA analysts' most recent estimates of vehicle weight-safety relationships address many of the deficiencies of earlier research. Large uncertainties in the estimates remain, however, that make it impossible to use this analysis to predict with a reasonable degree of precision the societal risk of vehicle downsizing and downweighting.[283]

Greene and Keller state firmly, "There is no fundamental scientific reason why decreasing the mass of all highway vehicles must result in more injuries and fatalities."[284]

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[279] *Effectiveness and impact of Corporate Average Fuel Economy (CAFE) standards*, Transportation Research Board, National Research Council, 2002
[280] *Relationship between vehicle size and fatality risk in model year 1985-93 passenger cars and light trucks*, Kahane, C.J., NHTSA Technical Report, DOT HS 808 570, 1997
[281] *Effectiveness and impact of Corporate Average Fuel Economy (CAFE) standards*, Transportation Research Board, National Research Council, 2002
[282] Ibid
[283] Ibid
[284] Ibid

The "fuel economy/safety tradeoff" dispute arises because it is difficult to discern the specific effects fuel economy regulations have had on cars and light truck designs. The Kahane study, one of the most advanced and scientific, has noted limitations—including Kahane's inability to statistically separate size and weight and the presence of confounding factors (such as driver behavior) "capable of changing the study's conclusions."[285]

David Greene restudied the issue subsequent to the 2002 NAS report and testified before the House Committee on Science on February 9, 2005, that "the aggregate national traffic fatality and fuel economy statistics provide no support for the hypothesis that increasing fuel economy led to increased traffic fatalities over the period 1966 to 2002."[286] The Chairman of the Committee, Sherwood Boehlert (R-NY), asked five expert witnesses if they agreed with the following statement, "The only way to improve fuel economy through increased CAFE standards would be to make vehicles lighter and therefore less safe." Each expert, including Michael Stanton, lobbyist for the Alliance of Automobile Manufacturers, said no.[287]

As with any interdependent design variable, setting fuel economy levels will inherently cause tradeoffs. The most important point to consider is whether or not manufacturers can practically design vehicles that are highly efficient *and* safe.

The *Wall Street Journal*, the very paper whose editors think CAFE kills people, reported in a front page story on September 26, 2005, that the safety of passenger vehicles is dependent on more than a simplistic balance between weight and fuel

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[285] Ibid
[286] "Experts: Technology exists to raise fuel economy of cars and trucks without reducing safety," news release, House Committee on Science, February 9, 2005
[287] Ibid

economy, noting that, "New studies highlight how other factors—including a car's size, body design and advanced technology—can do much to counteract the weight issue."[288] Rob Chapman, judge of the *Automotive News* PACE Awards for Innovation, wrote in the October 17, 2005, issue of *Automotive News* that "many developments today promise greatly improved occupant protection and decreased vehicle weight."[289]

The developments that the *Journal* and Chapman refer to include the use of advanced materials, creative structural designs, and weight-saving technology. The UltraLight Steel Auto Body project demonstrated how to achieve 25 to 36 percent mass savings without incurring cost or safety penalties.[290] Jaguar and Audi employ aluminum chassis that save hundred of pounds without sacrificing strength or safety. Electronic braking systems save weight by eliminating hydraulics. In short, there are a multitude of technologies at the disposal of automakers to produce more efficient (even lighter) and safer vehicles.

As a final note, the cumulative health benefit of fuel economy standards as manifested in environmental improvements has been given little attention. For example, by lowering fuel consumption, CAFE decreases emissions that generate smog, which studies have shown may be linked to and exacerbate childhood asthma,[291]in addition to other diseases. The National Academy of Sciences ignores this type of analysis in their report on CAFE's effectiveness.

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[288] "How US shifted gears to find small cars can be safe, too," Karen Lundegaard, *Wall Street Journal*, September 26, 2005
[289] "Lighter vehicles are not unsafe," Rob Chapman, *Automotive News*, October 17, 2005
[290] *UltraLight Steel Auto Body (ULSAB) Final Engineering Report*, March 1998, http://www.autosteel.org/ulsab/ulsab_eng_rpt_index.htm
[291] "In young rhesus monkey smog shown to set up lungs for asthma," news release, National Institute of Environmental Health Science, National Institutes of Health, October 12, 2000

Research and Development: PNGV and FreedomCAR

Federal and state governments have "played an active role in the research and development (R&D) of advanced automotive technologies" since the mid-1970's.[292] As early as 1976, Congress authorized the Department of Energy to support electric and hybrid vehicle research.[293] By directly funding R&D, government can subsidize research that industry finds too risky and would otherwise ignore. MIT's report on government involvement in the innovation process characterizes the underlying theory.

> Private firms may underinvest in the development of new technology (from a societal point of view) because they are not able to capture all of the benefits resulting from such investments. This situation, often called the "appropriability problem," occurs because the knowledge which results from investments in technical development can usually be readily acquired by others who will compete away part of the benefits from the original developer. Basic research in particular suffers from this problem because its output is usually an advance in scientific or technological knowledge that can subsequently be used in applied research and commercial development by a wide and often unforeseeable range of firms. Moreover, new technical developments also tend to be highly uncertain in terms of results and utility. Thus, direct government support of this class of R&D is necessary to correct for underinvestments.[294]

Yet recent government R&D initiatives in advanced vehicle technology, especially fuel-efficient technology, have been plagued by organizational ineffectiveness and misplaced priorities. Two major programs by the Clinton and Bush administrations in particular have highlighted institutional missteps that should be avoided in any cooperative R&D agenda between government and the auto industry such as: (1) the dominance of OEM concerns over government and supplier influences, (2) diminished

[292] *Advanced automotive technology: Visions of a super-efficient family car*, Office of Technology Assessment, 1995, OTA-ETI-638
[293] Ibid
[294] *Government involvement in the innovation process: a contractor's report to the Office of Technology Assessment*, Center for Policy Alternatives, MIT, 1978, p. 14

competition among manufacturers, and (3) objectives that promote technological trajectories at odds with program goals.

PNGV

In February 1993, President Clinton announced a new initiative that would "help the [US auto] industry develop critical new technology that can all but eliminate the environmental hazards of automobile use and operate from domestically produced fuels and facilitate the development of a new generation of automobiles."[295] The Partnership for a New Generation of Vehicles (PNGV), as the program became known, established a cooperative partnership in advanced research and development between the Big Three domestic automakers and five federal agencies: Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, and the National Science Foundation.[296] PNGV set a goal of producing an 80 mpg prototype vehicle within 10 years and, at the request of the Department of Commerce, established a standing committee at the National Research Council to conduct an annual review of the partnership.[297]

Rather than creating a new entity to oversee PNGV activity, existing programs were identified as PNGV-relevant by and subsumed within the structure.[298] Funding for the research classified as PNGV activities came from 12 sources, six House and six

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[295] *Technology for America's Economic Growth: A new direction to build economic strength*, President William J. Clinton, February 22, 1993

[296] The Department of Defense and the National Aeronautics and Space Administration also participated on steering and technical teams, but provided no funding.

[297] *Results of US-industry partnership to develop a new generation of vehicles*, General Accounting Office, March 2000

[298] *The machine that could: PNGV, a government-industry partnership*, Robert Chapman, RAND, 1998, p. 51

Senate appropriations bills, and the sums were large.[299] According to the General Accounting Office, "federal research in support of the partnership totaled about $1.25 billion" from fiscal year 1995 through fiscal year 1999.[300] This funding flowed from federal agencies to automakers, national laboratories, universities, and others. While this structure permitted a quick start, "the downside of such an approach was the lack of a discretionary, central program budget."[301]

PNGV also lacked central authority. The Department of Commerce was designated to lead the technical and policy task force for government, while the auto industry assumed the technical leadership of the overall PNGV program.[302] The Commerce Department's PNGV Secretariat served as the administrative arm for the participating agencies, but lacked the ability to formally reallocate funds or emphasize specific program directives. The former director of the PNGV Secretariat reports that the "central technical management of PNGV was primarily effected by suasion."[303]

The domestic auto industry participated in PNGV through its cooperative research body, the US Council for Automotive Research (USCAR), comprised of the Big Three: GM, Ford, and Chrysler (later Daimler-Chrysler).[304] USCAR amplified the native oligopoly behavior of the automotive sector. Acting in many PNGV programs as a coherent body, the umbrella of USCAR limited direct competition between industry participants and reduced any individual manufacturer's incentive to attempt original

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[299] Ibid
[300] *Cooperative Research: Results of U.S.-Industry partnership to develop a new generation of vehicles*, GAO, March 2000
[301] *The machine that could: PNGV, a government-industry partnership*, Robert Chapman, RAND, 1998, p.51
[302] Ibid
[303] Ibid
[304] *The Partnership for a new generation of vehicles (PNGV)*, Congressional Research Service, February 28, 1996

research. Such collaboration, previously forbidden by anti-trust laws, was encouraged under PNGV. [305]

Suppliers were all but ignored at the outset of the partnership. The Congressional Research Service reports that no PNGV money was allocated for "creative R&D with suppliers" for fiscal years 1995 or 1996.[306]

With little governmental control, massive collaboration among the Big Three, and zero innovative influence from suppliers, all three automakers chose to invest in diesel technology to meet the 80 mpg target set for a prototype vehicle, as outlined in the PNGV plan.[307] The National Research Council reported in 2001 that "In maintaining its quest for a vehicle with fuel consumption of 1.25 gallons per 100 miles (80 mpg) the PNGV has continued its focus on the diesel engine as the primary energy converter for the vehicle."[308] The Big Three planned to incorporate a small diesel engine in a hybrid powertrain, the most viable near-term means of maximizing fuel economy. Yet diesel technology poses such significant emissions problems (of particulate matter (PM) and nitrogen oxides (NOx)) that the NRC warned "the challenges of meeting the new California Air Resources Board (CARB) and the U.S. Environmental Protection Agency Tier 2 emission standards are a major hurdle for the [diesel] engine even when used in an HEV power train."[309]

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[305] *Partnership for a new generation of vehicles: a decade of lost opportunity*, Amy Buckley, 2001, available from author

[306] *The Partnership for a new generation of vehicles (PNGV)*, Congressional Research Service, February 28, 1996

[307] *Results of US-industry partnership to develop a new generation of vehicles*, General Accounting Office, March 2000

[308] *Review of the research program for the partnership for a new generation of vehicles*, Seventh report, National Research Council, 2001

[309] Ibid

In fact, during the course of the program, EPA announced final regulations (Tier 2, to be phased in beginning in 2004) for average fleet NOx and PM emissions that were more stringent than the original PNGV targets.[310] It appeared that the futuristic vehicles President Clinton had promised would "all but eliminate the environmental hazards of automobile use" would themselves have to be retooled to meet the nation's emission standards.

Eight years after Clinton's initial unveiling, PNGV proved to be riddled with administrative and technical errors that undercut the program's intent to accelerate the production of marketable vehicles with radically improved environmental performance. A new Republican administration also began to criticize PNGV. Energy Secretary Spencer Abraham, former governor of Michigan, disapproved of the direction PNGV had taken, saying in April of 2001 that is was "inconsistent with where the market is headed and where the automakers are headed."[311]

The market, in fact, had already introduced hybrid vehicles—though not as a result from any PNGV-related research. Honda and Toyota, excluded from the partnership, debuted on their own mass-produced gasoline-electric vehicles for US purchase in 2000, just as PNGV diesel-hybrid prototypes were being introduced. Ford Motor Company even decided to buy hybrid transaxle components from a Japanese supplier (Aisin AW) for its gasoline-electric hybrid Escape SUV while the American automaker received federal aid to develop domestic hybrid technology.[312]

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[310] PNGV targets in 1997 were 0.2 g/mile NOx and 0.1 g/mile PM. EPA Tier two averages are 0.07 g/ mile NOx and 0.01 g/mile PM
[311] "PNGV frets over Bush budget cuts," Harry Stoffer and John D. Stoll, *Automotive News*, April 16, 2001
[312] "Ford explains use of Japanese hybrid parts," Richard Truett, *Automotive News*, September 3, 2001

By the end of 2000, with the gasoline-hybrid Toyota Prius and Honda Civic already for sale in the US, GM, Ford and DaimlerChrysler had unveiled their first PNGV prototypes. The GM Precept, Ford Prodigy, and Dodge ESX3 all relied on diesel-hybrid powertrains and were estimated to achieve greater than 70 mpg.[313] While the productions of the concept cars satisfied one of the goals of PNGV, the market was led by the Japanese. American automakers designed their first marketable vehicles—such as the Ford Escape gasoline hybrid—in response to overseas pressure, not the PNGV program. They even bought or licensed Japanese technology. Moreover, it is unclear how much of the research classified as PNGV-related would have taken place without the program at all, as a consequence of manufacturers' scheduled R&D and contracts already in place at the national research labs.

At the end of 2001, PNGV participants could point to the commercial migration of a few promising technologies but no market-shifting influence. A PNGV director at the Department of Commerce testified before the Senate in December of that year, and after 8 years of research, listed only three production-available technologies that were the result of PNGV research.[314] Each one was an application of lightweight materials—a plastic hardtop in the model year 2001 Jeep Wrangler, 412 pounds of aluminum in the 2000 Lincoln LS, and a composite truck box on the 2001 Chevrolet Silverado.[315]

During the entire span of the PNGV activity, from 1993 to 2001, fuel economy standards for cars and light trucks stayed almost constant.[316] Some have argued that

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[313] Prepared statement of Dr. Claude C. Gravatt, Jr., Director, Manufacturing Competitiveness & PNGV, DOC, before the Committee on Commerce, Science, and Transportation, US Senate, December 6, 2001
[314] Ibid
[315] Ibid
[316] The standard for cars remained at 27.5 mpg. The standard for light trucks increased from 20.4 mpg in 1993 to 20.7 mpg in 1996 and remained at that level. (*Automobile and Light Truck Fuel Economy: Is CAFE up to Standards?*, Robert Bamberger, Congressional Research Service, September 16, 2002)

PNGV provided political cover for Detroit and the Clinton administration, which relied on diversionary and unproductive PNGV activity to resist increasing CAFE levels[317]and to permit collusion instead of competition between companies.[318]

FreedomCAR

In January 2002 President Bush replaced the Clinton-era PNGV with a similar "leapfrog" type joint R&D project, FreedomCAR, in which CAR stands for "Cooperative Automotive Research."[319] According to the Department of Energy, the goals of FreedomCAR are to

- Enhance energy efficiency and productivity;
- Bring clean, reliable, and affordable energy technologies to the marketplace; and
- Make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.[320]

The program, like PNGV, mostly ignores emerging technologies and focuses on high-risk endeavors: fuel cell power, hydrogen storage, hydrogen production and distribution, advanced combustion systems, advanced energy storage systems and lightweight materials.[321] FreedomCAR supports research on petroleum combustion engines, but its primary goal is hydrogen-based propulsion.

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317 "FreedomCAR needs firm milestones," editorial, *Automotive News*, January 14, 2002
318 *Partnership for a new generation of vehicles: a decade of lost opportunity*, Amy Buckley, 2001, available from author
319 *Multi-year Program Plan: FreedomCAR & Vehicle Technologies*, US DOE, August 2004
320 US Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/vehiclesandfuels/about/index.shtml
321 Ibid

FreedomCAR program goals differ from PNGV in a few notable ways. Rather than setting performance targets for a production-capable prototype vehicle, FreedomCAR establishes goals for underlying processes and technology that must be met in order to facilitate the long term goal of facilitating the transition to hydrogen-based vehicle systems.[322] FreedomCAR does not require participants to develop a prototype vehicle.

Unlike PNGV, which was a multi-agency program, the Department of Energy is the only government partner in FreedomCAR. Due to the extended focus on hydrogen fuel systems, however, the partnership was expanded to include government, the US Council for Automotive Research, and five energy companies: BP America, Chevron Corporation, ConocoPhillips, ExxonMobil Corporation, and Shell Hydrogen (US).[323] FreedomCAR envisions "by 2015, enablement of the private sector to make a decision about the commercialization of fuel-cell-powered personal transportation vehicles that run on economically competitive hydrogen produced from a variety of energy sources"[324] Such an objective is more than ambitious. *Automotive News* claims that the goal of FreedomCAR—practical fuel cell passenger vehicles—is "akin to President Kennedy's call 40 years ago for landing a man on the moon before the end of the 1960's."[325]

Actually, FreedomCAR may be even more technologically ambitious than the moon shot, considering cost constraints, and unfortunately, the program may have been constructed to repeat the unsuccessful PNGV model. Besides the three differences mentioned above (hydrogen fuel commitment, lack of a vehicle prototype requirement,

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[322] *Review of the research program of the FreedomCAR and fuel partnership*, National Research Council, First report, 2005
[323] Ibid
[324] Ibid
[325] "FreedomCAR needs firm milestones," opinion, *Automotive News*, January 14, 2002

reorganized agency and industry participants), FreedomCAR inherits many of the structural flaws of its older sibling. Doing away with PNGV and instituting FreedomCAR, in the view of *Automotive News*, “means that taxpayer money, above and beyond the more than $1.5 billion spent in the past decade, will keep flowing to the same automotive research, guided by the Big Three, that has recorded novel advances but no dramatic breakthroughs for production vehicles.”[326]

So far, that prediction has more or less been accurate. While the Partnership has published a list of key accomplishments (a summary of two to three dozen research initiatives),[327] no technology has yet moved from the lab to the showroom. All the while, funding for FreedomCAR activities has generally been on par with PNGV levels, and was approximately $310 million for fiscal year 2005.[328]

The National Research Council, in its first review of the program, finds that inappropriate and inflexible funding might fatally hinder FreedomCAR. “Of concern to the committee is the allocation by Congress of significant funds to specific organizations for activities that will contribute little to achieving the Partnership’s objectives. …This has negatively impacted projects in safety, the production of hydrogen from fossil fuel and renewable energy sources, and hydrogen storage. One possible result is that not enough knowledge and technology will be available by 2015, when commercial feasibility will be assessed, making a positive assessment less likely.”[329]

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[326] “FreedomCAR: real solution or tax waste?” Harry Stoffer, *Automotive News*, June 10, 2002
[327] 2004 FreedomCAR and Fuel Partnership Accomplishments, http://www.uscar.org/freedomcar/2004%20FreedomCARFP%20Accomplishments%20Final.pdf
[328] *Review of the research program of the FreedomCAR and fuel partnership*, National Research Council, First report, 2005
[329] Ibid

The Achilles heel of FreedomCAR, as the NRC repeatedly cautions, is the viability of clean and economical hydrogen production, transport, and energy conversion. To this end, the first review of the FreedomCAR program recommends that "An ongoing, integrated, well-to-wheels assessment should be made of the Partnership's progress toward its overall objectives of reducing the nation's dependence on oil and introducing hydrogen as a transportation fuel, if appropriate."[330]

Just such an analysis of well-to-wheels efficiency leads many to debate the value of a hydrogen-based program like FreedomCAR.

Hydrogen and Other Alternatives

Any analysis of the true efficiency of self-propelled vehicles must take into account the energy required to acquire the fuel source and transport it onboard—the so-called "well to tank efficiency"—and the losses inherent in the vehicle system (engine, transmission, drag, friction, etc.). The total ratio of energy out to energy in is the "well to wheel" efficiency of the vehicle.

Frank Kreith, emeritus professor of engineering at the University of Colorado, analyzed the well-to-wheel efficiency of 12 combinations of powertrain (conventional and hybrid spark ignition (SI), conventional and hybrid diesel, fuel cell, battery-electric), and alternative fuel (natural gas, Fisher-Tropsch diesel, Fisher-Tropsch diesel/gas mix, methanol, steam reformed hydrogen, electrolyzed hydrogen). Except for the electrolyzed

[330] Ibid

hydrogen, natural gas was considered the feedstock processed to produce each of the fuel alternatives to diesel and gasoline.[331]

Overall, the most efficient fuel/powertrain combinations are hybrid diesel or hybrid SI using Fisher-Tropsch diesel, natural gas, or a Fisher-Tropsch diesel/natural gas mix (30% - 32% efficient).[332] Hydrogen fuel cells using steam reformed natural gas follow close behind, yielding 27% well-to-wheel efficiency.[333] Hydrogen fuel cells using electrolyzed hydrogen are the least efficient (13%).[334]

Even assuming that steam reformed hydrogen fuel cells are chosen as the preferred technology of choice (though they are a less efficient system than hybrids), the enormous cost of a nationwide hydrogen infrastructure must be considered, which Argonne National Laboratory has estimated could be $500 billion or more.[335] Other potentially cost-prohibitive factors lie in the fuel cells themselves, which are currently made using a platinum catalyst. The precious metal requirement imposes significant cost hurdles for mass production, and finding an alternative material or method of manufacturing a fuel cell for motor vehicles is "Nobel Prize-winning work," according to Professor Donald Sadoway of MIT.[336]

Hydrogen-powered vehicle research is a high risk and long-term endeavor that lends itself perfectly to the nation's federally-funded laboratories, which can investigate the potential of fuel cell technology independently of automakers. More practical near-

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[331] "Gauging efficiency, well to wheel," Frank Kreith and R.E. West, *Mechanical Engineering*, June 2003
[332] Ibid
[333] Ibid
[334] Ibid
[335] *Cost of some hydrogen infrastructure options*, Mintz., M, Folga, S., Molberg, J., Gillette, J., Transportation Technology R & D Center, Argonne National Laboratory, January 16, 2002
[336] "Eco-friendly cars must travel a long way to reality," Elizabeth Thomson, MIT News Office, February 12, 2003, http://web.mit.edu/newsoffice/2003/hydrogen-0212.html

term research in alternative fuels should focus on vehicle technology that is closer to commercial production and also compatible with current infrastructure.

Other Alternatives – Natural gas, biofuels, and advanced hybrids

Natural gas, biofuels, and advanced hybrid technology all offer efficiency and emissions advantages when compared to conventional gasoline engines; and compared to hydrogen-based propulsion systems, each presents a much lower technological and infrastructural burden to surmount in order to be practical on a mass scale. Current investigations or prototypes of these less-consuming and less-polluting technologies show that each could displace petroleum-based vehicle platforms in some form much more quickly than hydrogen fuel cells.

Natural gas, for example, is cleaner burning than petroleum-based fuels, plentiful, and filling stations are already in place. Natural gas vehicles emit 25 percent less carbon dioxide and 35 to 60 percent less nitrogen oxides than a conventional gasoline engine,[337] and there are presently 1.9 million miles of natural gas distribution lines[338] and over 1,000 refueling stations.[339] The Honda Civic GX, powered by compressed natural gas, was awarded the Greenest Car award for 2005 by ACEEE, even ahead of gasoline-hybrids like the Honda Insight and Toyota Prius.[340]

Biofuels, made from recycled organic feedstock, have recently become much more efficient, economical, and popular. The wide variety of biofuels includes corn-

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[337] Compressed Natural Gas fact sheet, EPA, http://www.epa.gov/otaq/consumer/fuels/altfuels/420f00033.pdf

[338] American Gas Association, http://www.aga.org/Template.cfm?section=About_Natural_Gas

[339] Natural gas in the transportation sector, Natural Gas.org, http://www.naturalgas.org/overview/uses_transportation.asp

[340] A red-letter year for green vehicles: gasoline powered SUV earns spot on “Greenest vehicles of 2005” list, news release, ACEEE, February 15, 2005

based ethanol common in the US, sugar-based ethanol used in Brazil, cellusolic ethanol made from waste, trees and grass, and biodiesel. University of California Professor Dan Kammen, an author of the most recent study of ethanol use, says that while corn ethanol is slightly better than fossil fuel on a net energy basis, "you wouldn't go out and rebuild our economy around corn-based ethanol."[341] However, Kammen's report, published in *Science*, found that cellusolic ethanol offers even greater advantages than corn-based ethanol, and according to Kammen, "ethanol could replace 20 to 30 percent of fuel usage in this country with little effort in just a few years."[342] Kammen notes that almost all light trucks sold today are flex-fuel vehicles capable of burning E85, the ethanol/gasoline mix, though they are rarely advertised as such. Further, the cost of converting a conventional vehicle to one that is flex-fuel capable is only about $100.[343]

Besides alternative fuels, conventional hybrid technology can be improved to achieve well over 100 mpg by upgrading the batteries and controllers to permit an interface with the electric grid. So-called "plug-in hybrid electric vehicles" (PHEV) drastically increase fuel economy and can be programmed to help regulate power flow along the grid. If grid electricity is generated from clean or renewable sources—instead of from dirty coal or oil—the operation of plug-in hybrids releases significantly less emissions (including greenhouse gas emissions) than running petroleum-based vehicles. The California Cars Initiative (CalCars) modifies commercially-available Priuses to achieve 65 mpg for longer trips and up to infinite mpg (no gasoline use) for short trips.[344]

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[341] "Ethanol can replace gasoline with significant energy savings, comparable impact on greenhouse gases," UC Berkeley Press Release, January 26, 2006
[342] *Ethanol can contribute to energy and environmental goals*, Farrel, A.E., Plevin, R. J., Turner, B. T., Jones, A.D., O'Hare, M., Kammen, D., Science, January 27, 2006, pp. 506-508
[343] Ethanol can replace gasoline with significant energy savings, comparable impact on greenhouse gases, UC Berkeley Press Release, January 26, 2006
[344] Fact sheet: CalCars PRIUS+ Conversions, June 1, 2005

DaimlerChrysler has announced its own PHEV vehicle, the Sprinter.[345] According to Professor Kreith, "plug-in hybrids are the way to go."[346]

Put simply, the narrow emphasis on hydrogen fuel cells by the FreedomCAR program doesn't make much sense. There are other options available now, at low cost, that offer energy and environmental benefits. As the American Society of Chemical Engineers states, "the US must not abandon R&D on conventional energy systems which clearly have more near-term promise in reducing energy use, pollution and greenhouse gas emissions. Fuel cells and hydrogen are not a panacea for car and truck transportation, and may never be."

This is not the advice of novices considering an unknown technology. Fuel cells are useful in many applications, but to peg the future of clean and efficient motor vehicle transportation on one technology with demonstrable drawbacks while superior near-term options are extant is socially irresponsible and technologically ignorant. President Bush focuses the nation on a FreedomCAR not viable for many years and costing perhaps $1 trillion while current technology could be applied to immediately begin conserving energy and lower vehicle emissions.

The urgent need for sustainable motor vehicle transportation demands that national research initiatives deliver expedient solutions. It would be prudent to continue hydrogen research, but not without losing sight of all the applicable technology, from conventional combustion improvements to hybrid powertrains to biofuels, that could more readily improve the energy and environmental performance of the fleet.

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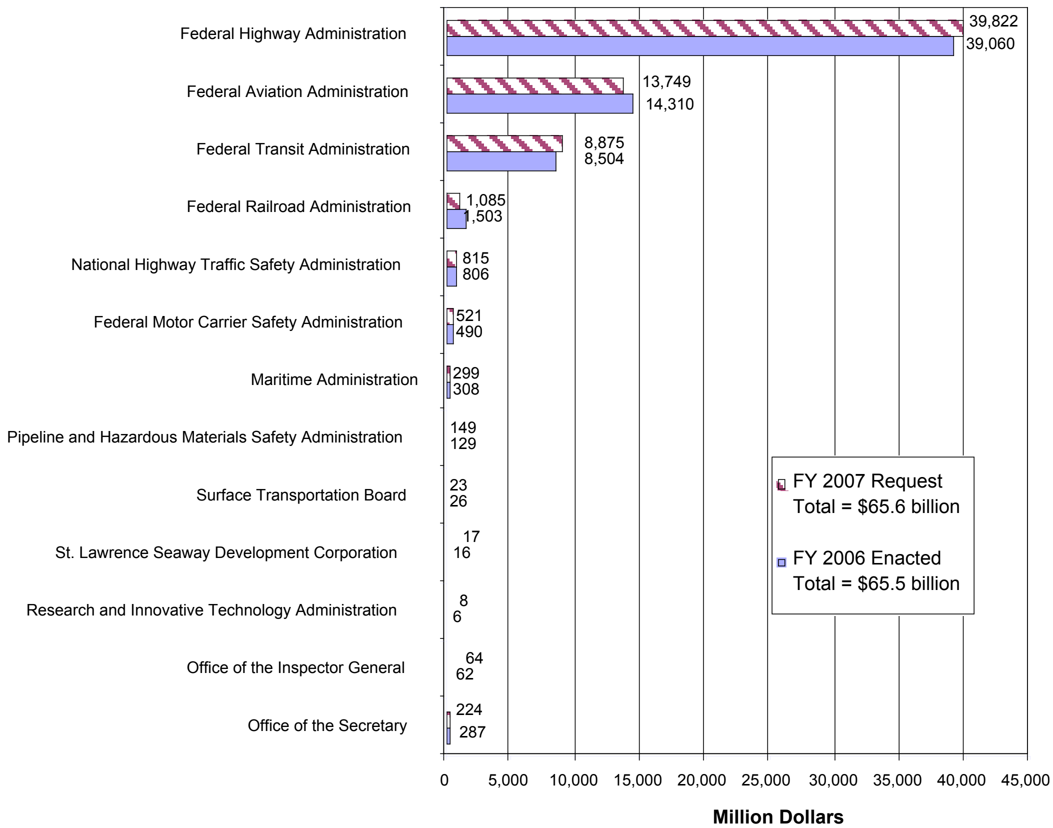
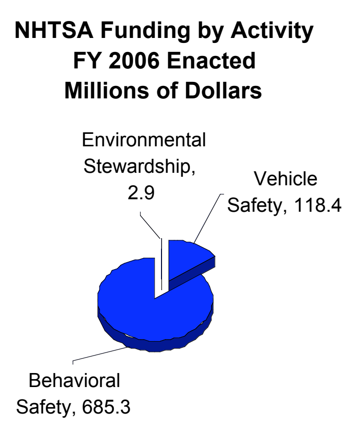
[345] "Diesel engine combined electric engine, Mercedes-Benz vehicle now also with hybrid drive," press release, DaimlerChrylsler, June 30, 2004, http://www.daimlerchrysler.com/dccom/0,,0-5-7165-1-428612-1-0-0-0-0-0-1371-7165-0-0-0-0-0-0-0,00.html
[346] Telephone conversation with Professor Frank Kreith, May 19, 2005

Appendix

Department of Transportation Budget



NHTSA Funding Breakdown FY 2006 Enacted	
	Million $
Highway Safety	44.5
Research and Development	30.8
Highway Traffic Safety Grants	572.4
General Administration	0.4
Salaries and Operating Expenses	37.1
Behavioral Safety	**685.3**
Rulemaking	12.7
Enforcement	18.1
Research and Development	41.1
General Administration	0.3
Salaries and Operating Expenses	46.2
Vehicle Safety	**118.4**
Environmental Stewardship	**2.9**
Total	806.5



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