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The New Car Assessment Program Suggested Approaches for Future Program Enhancements

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I. Introduction

The National Highway Traffic Safety Administration (NHTSA) is an integral part of the United States Department of Transportation (DOT) and its mission is to save lives, prevent injuries, and reduce traffic-related health care and other economic costs associated with motor vehicle use and highway travel. To accomplish this, NHTSA collects and analyzes motor vehicle crash data, and develops, promotes, and implements educational programs, vehicle safety standards, research, and enforcement programs.

In 1979, NHTSA created the New Car Assessment Program (NCAP) to improve occupant safety by developing and implementing meaningful and timely comparative safety information that encourages manufacturers to voluntarily improve the safety of their vehicles. Since that time, the agency has improved the program by adding rating programs, providing information to consumers in a more user friendly format, and substantially increasing accessibility to the information via the website, www.safercar.gov. The program has strongly influenced manufacturers to build vehicles that consistently achieve high ratings, thereby increasing the safety of vehicles.

However, the success of the NCAP requires change if manufacturers are to be continually challenged to make voluntary safety improvements to their vehicles. The opportunities for NCAP to be changed and improved are a result of:

- changes in the vehicle fleet and resulting crash dynamics
- advances in injury criteria and test devices
- the development and deployment of vehicle technologies that have the potential to improve safety, and
- new approaches in the presentation of NCAP ratings information for consumers

The agency plans to continue enhancing its NCAP crashworthiness (those aspects of a vehicle that protect occupants during a crash) and crash avoidance (those aspects of a vehicle that help avoid the crash) activities by challenging manufacturers, and by providing consumers with relevant information to aid them in their new car purchasing decisions. This document describes the opportunities that exist and some approaches to address them.

II. Overview of the New Car Assessment Program

History of NCAP

NHTSA established NCAP in response to Title II of the Motor Vehicle Information and Cost Savings Act of 1972. Its goal is to improve occupant protection by providing consumers with a measure of the relative safety of passenger vehicles to aid consumers in their purchasing decisions. As a result of consumer demand, vehicle manufacturers are encouraged to voluntarily design and produce safer vehicles.

The agency established a frontal impact test program whose protocol is based on Federal Motor Vehicle Safety Standard (FMVSS) No. 208 “Occupant Crash Protection” except that the frontal

NCAP test is conducted at 56 km/h (35 mi/h), rather than 48 km/h (30 mi/h) as required by FMVSS No. 208. Model year (MY) 1979 vehicles were the first tested and rated using this protocol. For several years, the agency provided consumers with the values recorded during frontal impact tests by the anthropomorphic test devices and the relationship of those values to established injury assessment references. After the Senate and Conference Appropriations Reports for Fiscal Year 1992 requested that NHTSA improve its methods of informing consumers about NCAP results, the agency established the five-star rating system, which was first used for MY 1994 vehicles.

The agency began testing and rating vehicles for side impact protection in the 1997 MY. As with the frontal program, the test protocol was based on an existing Federal standard, FMVSS No. 214 “Side Impact Protection”, and again the test speed was increased by 8 km/h (5 mi/h).¹

Starting with the 2001 MY, the agency began using NCAP to rate vehicles for rollover resistance based on a static measurement of a vehicle’s track width and the height of its center of gravity. The test protocol was not based on an existing Federal standard. The Transportation Recall, Enhancement, Accountability and Documentation (TREAD) Act of 2000 required the agency to extend rollover ratings to include a dynamic component. Beginning with the 2004 MY, NCAP rollover resistance ratings have been based on both the static measurements of a vehicle and the results of a dynamic test. The protocol for this dynamic test was also not based on an existing standard.

More recently, in an effort to improve the dissemination of NCAP ratings and as a result of the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA–LU) the agency has issued a Final Rule requiring manufacturers to place NCAP star ratings on the Monroney (automobile price sticker) label.² The rule has a September 1, 2007 compliance date.³

Comprehensive Review of NCAP

The agency believes that NCAP has helped make significant safety improvements by providing consumers with independent information that they can use in their purchasing decisions. This information has helped drive consumer demand for safety and manufacturers have responded by building vehicles that exceed Federal motor vehicle safety standards, thereby contributing to NHTSA’s mission of reducing death and injuries from motor vehicle crashes. Similarly, the consumer demand for vehicle safety information continues to grow, as exemplified by the fact that vehicle safety has become a major factor in the car purchasing decision process.⁴

¹ Subsequently for MY 2003 testing and beyond, the agency has been using a side impact dummy with a more advanced head and neck than is used in FMVSS No. 214 compliance testing.

² The Monroney label is required by the Automobile Information Disclosure Act (AIDA) Title 15, United States Code, Chapter 28, Sections 1231-1233. SAFETEA-LU P.L. 109-59 (August 10, 2005; 119 Stat. 1144) amended AIDA to require that NCAP ratings be placed on each vehicle required to have a Monroney label.

³ 71FR53572, Docket No. NHTSA-2006-25772

⁴ NHTSA Safercar.gov Exploratory Focus Groups: The Role of Safety in Recent Vehicle Purchases. Docket No. NHTSA-2004-19104.

Since its inception, the program has been expanded to provide consumers with front, side, and rollover vehicle ratings, as well as information about individual safety and convenience features on most passenger vehicles. As such, NCAP activities can be grouped into three main categories:

Ratings, where vehicles are assigned star ratings for their performance in frontal, side, and rollover testing, and child restraints are assigned letter grades based on their Ease of Use,

Features, where information on the inclusion of nearly 50 features (some which are proven safety features and others which are convenience features) is charted for hundreds of vehicle models, and

Outreach: where the information that NCAP collects on safety ratings and safety features is distributed to consumers through the brochures “Buying a Safer Car Guide” and “Buying a Safer Car Guide for Child Passengers” and is made available online at www.safercar.gov. Additionally, as of September 1, 2007, consumer outreach will also include point of sale information via the Monroney label.

By adding new programs and information to NCAP and by improving the dissemination and quality of the information, the agency has taken steps to innovate the program over the years. However, recent developments have indicated the need for a more simultaneous review of all NCAP vehicle safety activities so that NCAP continues to fully achieve its goals.

One development has been the amendments and proposed amendments to several Federal standards that serve as the basis for crashworthiness testing. As mentioned previously, the frontal crash program is based on FMVSS No. 208 “Occupant Crash Protection.” Amendments to this standard will soon require vehicles to comply at the same speed as NCAP, use more advanced injury criteria, and different sized dummies. These amendments will be phased in between September 1, 2007 and September 1, 2011.⁵ In light of these changes, NHTSA has been evaluating potential upgrades to the frontal NCAP and previously published two notices on the subject.⁶ The notices discussed several options and the likely improvements to safety if those options were implemented.

Similarly, with regard to side impact crashworthiness activities, the agency has proposed amendments to the FMVSS No. 214 “Side Impact Protection” standard. Currently, the side NCAP test procedures closely follow those of FMVSS No. 214. Proposed amendments to this standard include new tests and more advanced anthropomorphic test dummies and injury criteria than are currently used for side NCAP testing.⁷ The agency has not published any notices with regards to changes to side NCAP testing.

⁵ Increase test speed and advanced criteria: 65FR30680, Docket No. NHTSA-00-7013; 5th percentile dummy: 71FR51768, Docket No. NHTSA 2005-22323

⁶ Request for comments: 69FR 23078, Docket No. NHTSA-2004-18765. Notice of final decision: 70FR75536, Docket No. NHTSA 2004-18765

⁷ New testing NPRM: 69FR 27990, Docket No. NHTSA-2004-17694. New test devices NPRM for ES2 69FR55550, Docket No. NHTSA-2004-18864. NPRM for SID IIs: 69FR 70947, Docket No. NHTSA-2004-18865.

The agency has also proposed establishing a new safety standard (FMVSS No. 126) to require electronic stability control (ESC) on all light duty passenger vehicles beginning in MY 2009.⁸ ESC can prevent a large percentage of loss-of-control crashes which expose vehicles to the off-road tripping mechanisms that cause most rollovers. By reducing exposure to run-off-the-road crashes, an ESC requirement would result in a large reduction in rollover fatalities. The agency has not published any notices with regards to changes to the rollover ratings program to reflect ESC equipped vehicles.

Congressional interest has also indicated a need for a more comprehensive review of the NCAP. In April of 2005, the Government Accountability Office (GAO) published a report based on its study of NCAP.⁹ The study examined the impact of NCAP on vehicle safety and investigated opportunities to enhance its effectiveness. The GAO's general recommendations were that "NHTSA examine the direction of the New Car Assessment Program to ensure that it maintains its relevance in improving vehicle safety, including identifying tests that best address the fatalities occurring on the nation's roads," and that "NHTSA enhance the presentation and timeliness of the information provided to the public." More specifically, the GAO cited the recent abundance of four- and five-star ratings and suggested that pending changes to compliance testing that would render NCAP's tests less meaningful. It also pointed out that NHTSA must update NCAP to stay current with changes in the characteristics of the fleet. NHTSA generally agreed with GAO's findings.

Finally, along with NHTSA's vehicle rating programs, other countries around the world have also established their own version of NHTSA's NCAP to help educate and to provide safety ratings to the public. Currently, there exist NCAPs in Europe, Japan, Australia, Korea, and China. Similarly in the US, there exists the Insurance Institute for Highway Safety (IIHS) and Consumers Union (publisher of *Consumer Reports*) that also serve to generate and publish vehicle ratings. Over the years, many of these programs have also implemented changes to their dissemination methods, testing practices, test devices, and rating systems. While many of the changes and the scientific basis for these changes have not been documented, they nevertheless serve as areas of consideration for what changes could be made to the NHTSA's NCAP, especially given that these programs share common interests in providing ratings information to consumers so that market forces can be generated to improve safety.

III. Approaches for Enhancing NCAP

NCAP's goal is to enhance occupant safety by generating market demand for safety features and performance that go beyond Federal requirements. Over the years, the agency has achieved this by developing information that is easy to understand and encouraging the implementation of real safety improvements into the vehicle fleet without compromising the program's fundamental principles or damaging its credibility and integrity. As such, in developing new approaches to enhance NCAP, the agency has followed several guiding principles.

⁸ ESC NPRM: 71FR54712, Docket No. NHTSA-2006-25699

⁹GAO-05-370, Report to Congressional Committees, Vehicle Safety, "Opportunities Exist to Enhance NHTSA's New Car Assessment Program."

The primary guiding principle for any change in NCAP is that a change will only be considered if there is definable data to support the conclusion that the change is likely to provide significant safety benefits. Other considerations include whether or not the change would:

1. result in safety benefits that are evident but for which a regulation may not be the best approach
2. distinguish meaningful performance differences between vehicles
3. spur research and the achievement of safety goals that exceed regulatory requirements
4. stimulate the use of information so that it is more widely used

This section describes the approaches that the agency is seeking comment on in its pursuit to enhance both the crashworthiness and crash avoidance aspects of NCAP. While the agency will continually look for ways to make meaningful improvements to the program, the approaches described below represent our current thinking for improving the program. The agency intends to refine or revise these approaches as new information or new advancements occur and based on comments from the public.

Changes in the vehicle fleet, crash characteristics, test devices, and injury criteria

Current NCAP tests were developed to address particular types of crashes. This section discusses approaches the agency is considering to better represent the current vehicle fleet, crash characteristics, and common injuries. This discussion is organized by type of crash.

Frontal Crashes

Description of issue

Currently, NHTSA has three frontal crashworthiness tests specified in FMVSS No. 208. They are the full-frontal, right and left-oblique frontal (± 30 degrees from perpendicular), and 40 percent offset-frontal.

Categorizing the National Automotive Sampling System (NASS) data into these three types of crash modes provides a method of estimating the injuries that could be addressed by tests that are readily available. Using the NASS, frontal crashes were grouped into full-frontal, oblique-frontal, and offset-frontal. Real world collisions with narrow objects were grouped as frontal-pole crashes. As such, all frontal crashes and their corresponding overlap (left, right, or center of the vehicle) with the struck object can be grouped using the following definitions.

1. Full: Direction of force 11 to 1 o'clock and 66 to 100 percent overlap
2. Oblique: Direction of force 10 and 2 o'clock and 66 to 100 percent overlap
3. Offset: Direction of force 10 to 2 o'clock and 26 to 65 percent overlap
4. Pole: Direction of force 10 to 2 o'clock and 0 to 25 percent overlap

The data were then separated into front and rear seat belted occupants. Table 1 indicates that for calendar years 1995-2004, there were 3,181 Abbreviated Injury Scale (AIS) 1+ injuries for all categories for occupants in rear seats versus 105,379 in the front seat. This general trend was

true regardless of AIS level and consequently, the analysis focused on front seat occupant injuries.

Table 1: Frontal Seat vs Rear Seat: AIS 1+ Injuries

Crash mode	Front Seat	Rear Seat
Full frontal	53,772	1,632
Oblique frontal	1,521	51
Offset frontal	37,099	1,428
Frontal pole	12,987	70
Total	105,379	3,181

Table 2 indicates that by further restricting the NASS data to belted, front seat occupants, most injuries occur in full and offset-frontal crashes. This was also true regardless of injury severity.

Table 2: Injuries by Frontal Crash Mode

Crash Mode	AIS 1+	AIS 2+	AIS 3+
Full frontal	53,772	13,259	1,310
Oblique frontal	1521	445	1
Offset frontal	37,099	10,847	1,438
Frontal Pole	12,987	3,501	208

The agency also evaluated the speed at which AIS 2+ injuries were occurring and the ages of the occupants. Table 3 indicates that the maximum number of injuries occurred in full-frontal crashes at changes in velocities from 0 to 25 miles per hour, ages 16 to 60-year-olds, and to front seat occupants. Within this grouping, the knee/thigh/hip (KTH) and lower legs have the highest incidence of AIS 2+ injuries, 12,887 and 8,713, respectively. Neither of these regions is currently rated by NCAP.

Table 3: Frontal AIS 2+ Injuries with Speed and Age Categories

Speed	Age	AIS 2+
0-25 mph	0-8	506
0-25 mph	9-15	802
0-25 mph	16-60	38,230
0-25 mph	61+	5,717
26-40 mph	ALL	6,898

Neither NCAP nor FMVSS 208 has tested belted occupants in frontal crashes at speeds below 25 mph. Therefore a low speed rating program could provide opportunities for injury reduction in these ranges. NCAP has been testing and rating for years and for MY 2006, approximately 95 percent of new vehicles achieved a four-or five-star driver rating. Consequently, current head and chest Injury Assessment Reference Values (IARVs), tests, and resulting ratings are not likely

to further reduce high speed or low speed injuries. However, there may be opportunities to reduce other IARVs and thus, real world injuries for body regions that are currently not rated.

A preliminary agency assessment of the KTH injury risk curve indicates that a 25% risk of an AIS 2+ injury is associated with a compressive axial force on each femur of 7,000 N (1,574 lb).¹⁰ NCAP femur results in Table 4, for model years 1995 through 2006, show the number of times femur readings exceeded 7,000 N (1,574 lb).

Table 4: Left and Right Femur readings from NCAP tests that exceeded 7,000 N

	Driver		Passenger		<i>Total NCAP Tests</i>
	Left Femur	Right Femur	Left Femur	Right Femur	
1998	3	2	2	0	52
1999	7	4	4	2	35
2000	3	2	0	0	28
2001	3	6	3	0	61
2002	2	0	2	1	48
2003	0	4	1	0	40
2004	1	3	0	0	49
2005	2	2	0	1	48
2006	1	0	1	0	38
Total	22	23	13	4	399
	62				

Tables 2 and 3 provide a summary of the NASS data analysis restricted to AIS 2+ injuries. AIS 2+ injuries are being used for this evaluation because although these injuries are not life threatening, they are not easily healed and carry a high societal cost. The data indicate that future tests should focus on full-frontal crashes, front seat occupants, lower speeds, and 16- to 60- year-old adults.¹¹ However, current test devices and injury criteria have not been evaluated at such low speeds or for the subject target population. Additionally, at the current speed of 35 mph, the agency has not completed injury criteria development to improve safety for other body regions like KTH, and lower leg. Therefore there may be opportunity to use the existing test for potential improvement in these body regions.

Approaches to enhancing Frontal NCAP

- ***Maintain the current 35 mph test protocol with the Hybrid III 50th percentile male dummy, complete development of a KTH injury criterion, and incorporate KTH injuries into the rating.*** Other injury criteria such as chest deflection and neck injury

¹⁰ Rupp, J.D. (2006). Biomechanics of hip fractures in frontal motor-vehicle crashes. Doctoral Dissertation. The University of Michigan, Ann Arbor, MI.

¹¹ The agency notes that offset-frontal crashes also represent a significant portion of the injuries described in tables 2 and 3 and that the agency is currently researching a viable approach to address these injuries.

tend to measure well below the FMVSS No. 208 IARVs so their inclusion into the frontal crash rating would likely not result in meaningful improvements to occupant safety.

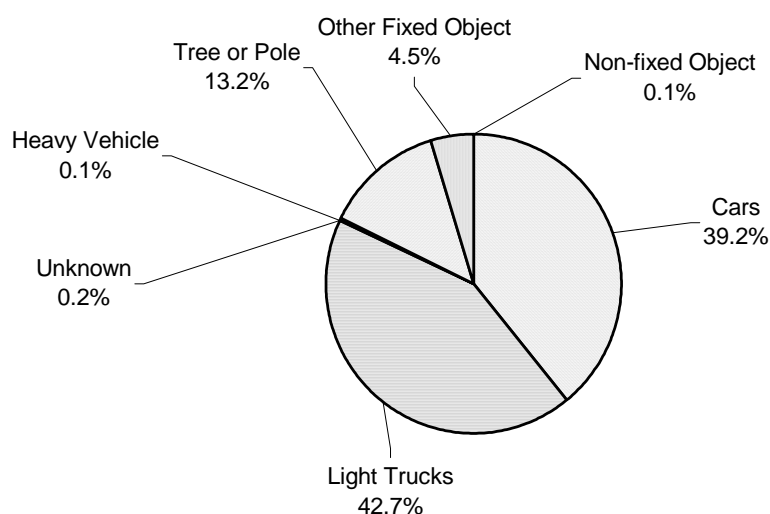
- **Determine whether injury measures obtained below the knee using either the Denton or the Thor legs are predictive of real world injury.** This research would evaluate whether the dummy readings are indicative of real world injuries. The readings could also be added to the rating thereby providing the agency with a complimentary measurement not currently required in FMVSS No. 208.¹² This would enhance the agency's ability to address AIS 2+ leg injuries, which are costly to society.
- **Evaluate lower speed test(s).** The research would determine whether current IARVs need to be adjusted or new ones developed, and assess the ability of the devices and test procedures to accurately measure those injury assessment values.

Side Crashes

Description of issue

The majority of side impact crashes with serious injuries (AIS 3+) involve the primary vehicle being impacted in the side by light trucks or cars. Approximately 82 percent of all serious injuries (36,692) to occupants result from subject vehicles being hit by passenger cars (14,383) or light trucks (15,661). Figure 1 shows the distribution of crashes by type of impacting object using 1995-2004 NASS data.

Figure 1. Distribution of serious injuries (AIS 3+) in side impact crashes by type of object



¹² Since acceleration without intrusion can cause lower leg injuries, an approach is to find out if the frontal NCAP test (the acceleration component of the toe board) can address acceleration based lower-leg injuries. The research may determine that the frontal NCAP will capture lower leg injuries that may not be addressed by frontal-offset testing.

In side impact crashes representing the current moving deformable barrier test, approximately 46 percent (11,459 AIS 3+) of serious injuries occurred in vehicle-to-vehicle side impact crashes at changes in velocity of 20 mph or lower. About 70 percent (17,097 AIS 3+) of the injuries occurred at a changes in velocity of 25 mph or lower. When examining injuries at these crash speeds, 34% of occupants had an AIS 3+ head injury in a change in velocity range of 0-20 mph in vehicle-to-vehicle side crashes. The chest injuries were the most frequent serious AIS 3+ injuries (51%, when head/face, neck, back/chest, abdomen/pelvis and legs are considered).

Figures 2 and 3 illustrate the distribution of serious injuries in side impact crashes with other vehicles and narrow objects for occupants who received at least one AIS 3+ injury. The pattern of injuries is similar for these two categories of side impact crashes, but chest and back injuries were somewhat more frequent when there was a striking vehicle than when there was a narrow object impact¹³.

Figure 2. Distribution of serious injuries (AIS 3+) with striking vehicles in side impact crashes with Delta-V's up to 20 mph

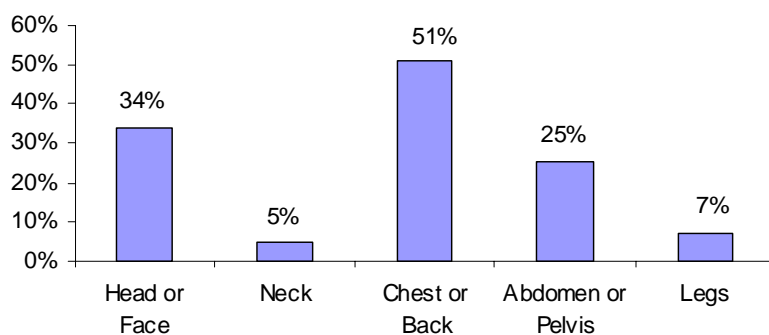
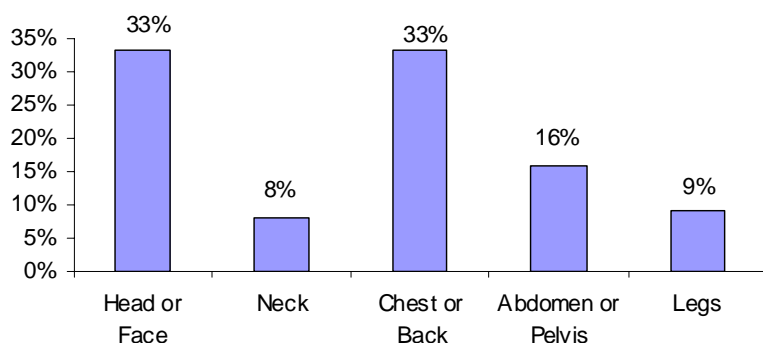


Figure 3. Distribution of serious injuries (AIS 3+) with narrow object impact in side impact crashes



The impact conditions for the FMVSS No. 214 barrier test were developed more than twenty years ago to represent side impacts resulting in serious injuries at that time. Due to improvements in side impact occupant protection systems, especially side impact air bags, and

¹³ Since an occupant can receive more than one AIS 3+ injury, these percentages can add to over 100%.

the changed characteristics of today's light passenger vehicle fleet, these may not be the same impact conditions that result in serious injuries for the fleet of today and in the future.

The current side NCAP has the same impact conditions as the FMVSS No. 214 barrier test, except it uses a higher impact speed. It simulates vehicle-to-vehicle crashes at the typical delta-V for the struck vehicle of about 20 miles per hour, which is two or three miles per hour higher than the FMVSS No. 214 test.¹⁴ The current moving deformable barrier (MDB) was designed to represent the height and weight of an early 1980's passenger car and the stiffness of a 1980's era light truck.

The current anthropomorphic test device used in side NCAP is the SID-H3 test dummy and represents the 50th percentile male occupant. Ratings are based on chest injury only. Average Thoracic Trauma Index (TTI) values are approximately 55 for all MY 03 thru MY 06 vehicles.¹⁵ Based on these values, there is a 19 percent risk of AIS 3+ and 4% risk of AIS 4+ torso injuries. Head injuries are not included in the rating but are reported and noted as safety concerns when the head acceleration values exceed 1,000.

Eighty-seven percent of MY 06 vehicles received four- or five- stars for the driver. Consequently, the side NCAP ratings are reaching the point of providing little discrimination between vehicles. Since the fleet has changed both in terms of weight and front end characteristics, and since the side impact occupant protection systems have improved over the years, it is necessary to revisit the design of the side test to better reflect what is occurring in the real world when serious injuries result.

Approaches to enhancing Side NCAP

- ***The agency can use NCAP to encourage head protection by using the pole test proposed for FMVSS No. 214 until such time as the rule is fully phased-in.*** This test would continue to measure performance while at the same time indicate to consumers the importance of good head protection devices.¹⁶ Some research will be needed to develop a new rating system. Also, since both the ES-2re and SID-II dummies were specified for use in the proposed FMVSS No. 214 pole test, a decision will be made on whether one or a combination of these dummies would be used for ratings in the NCAP program.
- ***Research that focuses on the assessment of the injury mechanisms in a fully equipped side impact air bag and window curtain fleet needs to be conducted.*** The purpose is to evaluate how serious injuries occur in a fleet fully equipped with inflatable head protection and develop test procedures to reflect these impact conditions. The outcome

¹⁴ The barrier impact speed is about 38.5 mph for side NCAP and 33.5 mph for FMVSS 214.

¹⁵ The TTI is an injury assessment reference value that describes injury severity to an occupant's torso region

¹⁶ Vehicle manufacturers, in addition to structural improvements, would likely need to install head air bags in order to have good performance in any pole test. For occupants in far-side seating positions, NHTSA found that having an air bag for the torso and head reduced fatality risk in all side impacts, except far-side impacts to belted occupants, by 20 percent for driver and right-front passenger. See the 214-PRIA for additional discussion. When the analysis is limited to belted far-side occupants, NHTSA found that the fatality reduction for torso plus head air bags is only 8 percent and it is not statistically significant.

of this research could be used to further raise the level of side impact protection. More research is needed, as outlined below:

- ***A new barrier test protocol.*** The research will evaluate the side impact crash conditions that generate serious injuries to the occupants of the struck vehicles in the new fleet. This includes examining vehicle orientation at impact, vehicle trajectory at impact (e.g. barrier impact angle), and impact location.
- ***Increase speed.*** This strategy would potentially address the serious injuries that occur in the 21-25 mph delta-V range. The 21-25 mph delta-V range has the highest number of serious injuries (5,638) in vehicle-to-vehicle side crashes.
- ***Increase barrier weight, change geometry, and/or modify stiffness characteristics.*** This is an opportunity to refine barrier characteristics as the fleet changes. It is also a chance to evaluate the different MDB characteristics around the world in hopes of developing one common barrier. This strategy could adopt the IIHS barrier or build on previous research to develop other methods.
- ***Use of new dummies, such as WorldSID.*** Considerable effort by industry and governments has been devoted to development of WorldSID, a new 50th percentile side impact male dummy. NHTSA is evaluating the WorldSID dummy. If development progresses to the stage that it is ready for incorporation into NHTSA's test dummy regulation (49 CFR Part 572), inclusion in side NCAP would follow.
- ***Develop additional lateral injury criteria.*** If new dummies are used, the agency would take full advantage of new dummy capabilities to measure additional lateral injuries.

Rollover Crashes

Description of issue

Although the proportion of crashes that result in rollover is low,¹⁷ these crashes injure and kill a significant number of vehicle occupants. According to the 2004 Fatality Analysis Reporting System (FARS), 10,555 people were killed in light vehicle rollover crashes, which represents 33 percent of the occupants killed that year in all crashes. Of those, 8,567 were killed in single-vehicle rollover crashes. The 2004 FARS data show that 55 percent of light vehicle occupant fatalities in single-vehicle crashes were involved in a rollover event.

For 2000-2004, the NASS shows that 280,000 light vehicles were towed from a police-reported rollover crash each year (on average), and that 29,000 occupants of these vehicles were seriously injured. The present rollover resistance ratings estimate the risk of rollover if a vehicle is

¹⁷ The proportion of all police reported crashes in 2003 by vehicle type that resulted in rollover was 1.8 percent for cars, 1.9 percent for vans, 3.7 percent for pickup trucks and 5.3 percent for SUVs as estimated by NASS GES.

involved in a single-vehicle crash. Estimates from NASS indicate that 82 percent of tow-away rollovers were single-vehicle crashes, and that 88 percent of the single-vehicle rollover crashes occurred after the vehicle left the roadway.

NCAP rollover resistance ratings predict the risk of rollover in the event of a single-vehicle crash. These ratings are based upon a geometric measurement called the Static Stability Factor (SSF), derived from the height of a vehicle's center of gravity and its track width, and a road maneuver test called the Fishhook test. Ratings are determined using a risk model which was derived from the roll/no roll outcomes of 96,000 single-vehicle crashes of vehicles with known SSF and Fishhook test results. The vast majority of rollovers occur when a vehicle leaves the roadway (usually due to loss of control) and is tripped by digging its tires into soft soil or encountering such things as curbs, ditches, and guard rails. The SSF is highly predictive of these "tripped rollovers" and is the most influential component of the NCAP measurements because most rollovers occur as a result of tripping mechanisms. The Fishhook test evaluates a vehicle's susceptibility to an on-road un-tripped rollover in which the vehicle is subjected to tire/road interface friction forces in extreme maneuvers, but not to the much greater forces caused by off-road tripping mechanisms. It is less influential than SSF in the rollover rating because even a less susceptible vehicle is far more likely to roll over as a result of encountering a tripping mechanism.

NHTSA estimates that its proposal to require ESC in all light vehicles by 2012 will result in a significant reduction in run-off-road crashes. Based on NHTSA's study of crash statistics of current vehicles with ESC, we estimate that ESC-equipped passenger cars will be involved in 34 percent fewer single vehicle crashes and 71 percent fewer single vehicle crashes resulting in rollover. We also estimate that ESC-equipped SUVs will be involved in 59 percent fewer single vehicle crashes and 84 percent fewer single vehicle crashes that result in rollover.

Most of the anticipated rollover reduction from ESC is not a consequence of ESC increasing rollover resistance. Rather, it is a consequence of ESC preventing a large number of single-vehicle loss-of-control crashes in which the vehicle leaves the roadway and subsequently is exposed to soft soil, ditches, and other conditions that cause tripped rollovers. In the case of passenger cars (which do not tip up in the Fishhook test), ESC would not affect the NCAP rollover resistance rating that predicts the number of rollovers per 100 single-vehicle crashes. However, the absolute number of rollover crashes would be greatly decreased by the large reduction in single-vehicle crashes as a result of ESC. In other words, ESC prevents rollovers by keeping more vehicles on the road and away from tripping mechanisms.

None of the SUVs with ESC rated by NCAP have tipped up in the Fishhook test. This effect of ESC shows improved rollover resistance scores for SUVs. ESC's greatest impact on preventing rollovers of SUVs is the same as its impact on preventing rollovers of cars. Namely, by reducing loss-of-control crashes, ESC keeps more SUVs on the road and away from tripping mechanisms.

Single-vehicle crashes resulting in rollover, in particular, are dramatically reduced by ESC. This is because higher speeds and loss of control are associated with rollover crashes, and ESC is designed to assist the driver in maintaining directional control. However, it is possible that ESC causes a reduction in rollovers even in circumstances in which the driver could not avoid

roadway departure entirely. It is possible that if ESC permits even partial control, the driver may be allowed to slow down more and leave the road at a more favorable angle, thereby influencing rollover risk.

Approaches to enhancing Rollover NCAP

- ***Track the state data to understand the rollover rate (rollovers per 100 single-vehicle crashes) and the single-vehicle crash rate of all vehicles with ESC to create a new rollover risk model.*** Another model for only ESC vehicles would be developed and refined as more crash data of ESC vehicles becomes available. When sufficient data are available, it will be possible to determine whether the current model is accurate for ESC vehicles or whether ESC reduces rollover risk further than currently predicted.

Rear Crashes

Description of issue

Consumers are concerned about rear impact crashes. According to Frost and Sullivan, 48% of respondents feel most vulnerable in rear impact crashes.¹⁸ Currently NHTSA provides no consumer information on rear impacts.

While NHTSA has recently upgraded FMVSS No. 202 "Head Restraints" to address whiplash injuries, the NASS data indicate that of the injuries to other upper-body regions are also occurring. Among AIS 1+ injured people in non-rollover crashes with damage to the rear of the vehicle, 44,739 had at least one head or face injury, 77,134 had at least one back or chest injury, and 103,195 had at least one neck injury. Within the neck injuries, 86,402 were attributed to whiplash. Table 5 shows the breakdown for other AIS levels.

Table 5: Upper Body Injuries in Rear Impacts

Crash Mode	AIS 1+	AIS 2+	AIS 3+
Head or face	44,739	3,135	914
Back or chest	77,134	1,986	767
Neck	103,195	738	503
Whiplash	86,402	Not Applicable	Not Applicable
Total for <u>all</u> body regions	180,287	8,393	1,884

Approaches:

Based on consumer concerns, NHTSA will explore providing consumers with basic information concerning rear impact crashes in NCAP publications. This could include:

¹⁸ *Customer Desirability and Willingness to Pay for Active and Passive Safety Systems*, Frost & Sullivan, July 6, 2005 (www.frost.com)

- Real world safety data by vehicle classes
- Links to IIHS rear crash test results
- Safety tips, such as proper adjustment of head restraints, safe driving behavior to avoid rear impacts, and what to do if you see a vehicle about to hit you in the rear.

In the long term, a dynamic test that addresses those injuries not covered by the agency's current standards could be investigated as a possible ratings program.

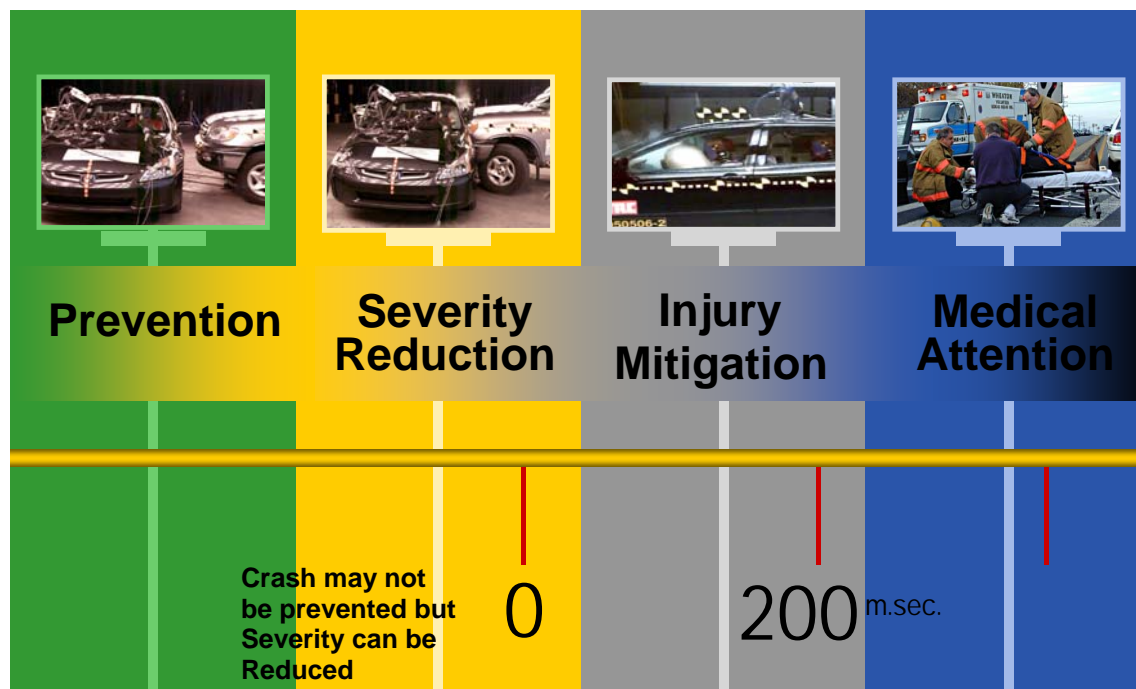
Encourage the Implementation and Consumer Demand of Crash Avoidance Technologies

Description of issue

Various crash avoidance technologies have been developed and are beginning to be offered in the current vehicle fleet. Some of these technologies have shown effectiveness in reducing the number of relevant crashes in NHTSA-sponsored field operational tests. Technologies that have been tested include rear end crash warning systems, road departure crash warning systems, a rollover advisory system for heavy trucks, and curve-speed warning systems. While the agency collects information on many technologies, to date, the agency has not attempted to separate safety technologies from other vehicle technologies.

The crash timeline is shown in Figure 4. There are four stages in the timeline: prevention, severity reduction, injury mitigation, and medical attention. Safety ratings currently focus on injury mitigation from certain types of crashes. Except for the NCAP rollover ratings, prevention (in the sense of avoiding the crash) and severity reduction are not included in the safety ratings, and since a vehicle that is less likely to crash is safer for its occupants, NHTSA believes crash avoidance is one area in which NCAP could be used to improve safety by addressing beneficial crash avoidance technologies.

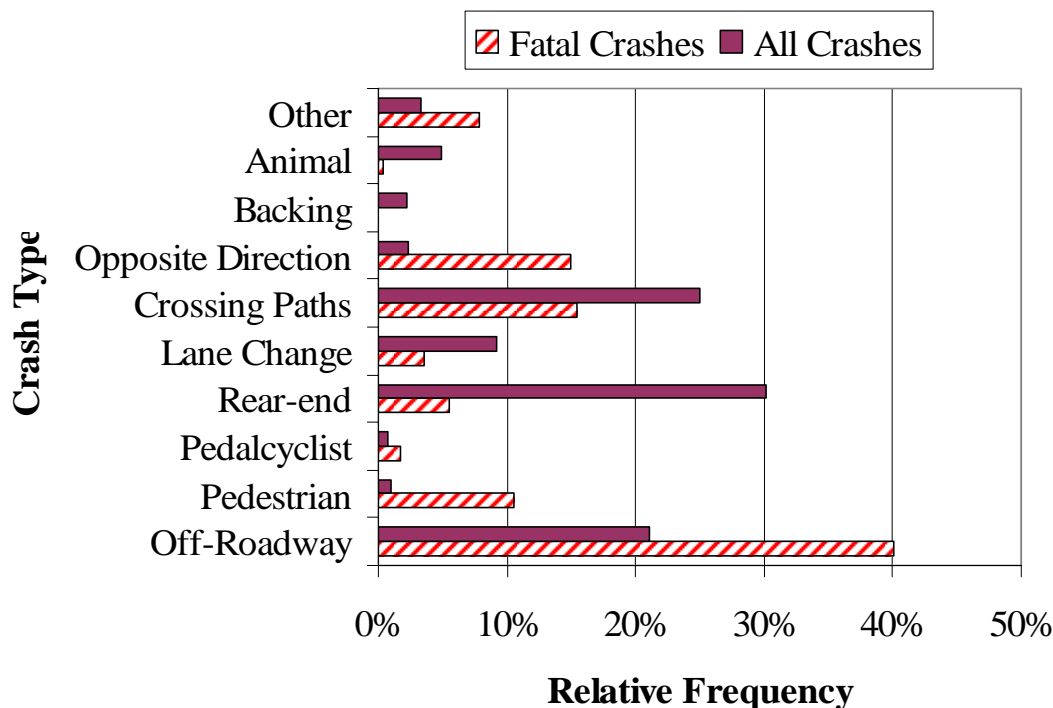
Figure 4. Crash timeline



Developing approaches for crash avoidance safety technologies is challenging in that, prior to significant market penetration, it is difficult to determine real world effectiveness and safety benefits of new technologies. Additionally, manufacturers differ on priority, approaches, and names of technologies. Even within a specific type of technology, systems can differ from one manufacturer to the next in terms of driver-vehicle interface design and whether or not its performance is based on the vehicle and or algorithm characteristics. Similarly, because of the dynamic nature of the market, consumers do not always have clear information on which technologies are beneficial and which are simply convenience features. Finally, crash avoidance technologies consist in large part of electronic hardware components and software and like other segments of the electronics industry, the vehicle electronics area is constantly evolving. While there are numerous challenges, the agency believes that it has a role in encouraging the development and deployment of all beneficial safety technologies especially, crash avoidance technologies. The agency believes that by providing consumers with information (whether that occurs with ratings or basic information about these systems) the agency could encourage the purchase of beneficial technologies, thus improving safety.

As shown in Figure 5, four crash types: run-off-the-road, rear-end, lane change, and crossing path crashes account for nearly 85 percent of all crashes. Two of these crash types, run-off-the-road and crossing path, account for approximately 55 percent of the fatal crashes and rear end crashes are the single largest group of crashes.

Figure 5. Distribution of types of crashes from the 2004 Fatality Analysis Reporting System (FARS), and all General Estimate System (GES) crashes



Using the same 2004 data, as shown in Table 6, these four crash types represent about 82 percent of the total maximum AIS (MAIS) 3+ injuries.¹⁹ Thus, if NCAP could promote technologies that effectively address these four crash types, there is the potential for significant safety benefits. This would focus new technology on the highest frequency crash types and would be consistent with NHTSA's advanced technology Intelligent Transportation Systems (ITS) program which has been working cooperatively with the automotive industry over the past several years to develop and evaluate crash avoidance systems to address these crash types.

Table 6. Estimated MAIS 3+ Injuries by crash type

Crossing Path	43000	30%
Run-Off Road	39000	27%
Rear End	28000	19%
Lane Change	9000	6%
Other	28000	18%
Totals	147000	100%

Existing technologies were mapped to each of the four problem areas. Note that the following technologies are not necessarily all commercially available at this time and have widely differing levels of technical maturity. Some are experimental or prototypes, while others are

¹⁹ See Appendix A for methodology explanation

commercially available. However, they are all technologies that have had significant research performed by both industry and NHTSA.

Technologies intended to address run-off-road crashes include:

- Lane tracking with lane departure warning
- Lane tracking with steering assist (lane keeping assist)
- Curve speed warning
- Electronic Stability Control (ESC)

Technologies intended to address rear end crashes are:

- Rear end crash warning/avoidance: Forward vehicle sensing (typically via radar) with warning and/or braking

Technologies intended to address lane change/merge crashes are:

- Side object detection with warning and/or steering assist.

Technologies intended to address crossing path (intersection) crashes are:

- Systems that utilize vehicle to vehicle and/or vehicle to infrastructure communications coupled with driver warning and/or vehicle braking control.

After mapping technology options to high frequency crash problems, priority technologies were identified based on technical maturity, fleet availability, and available benefits data. Three technologies fit these criteria and were identified:

- Stability Control (Electronic Stability Control) – These systems prevent loss of control events associated with excessive vehicle yaw, which often result in run-off-the-road crashes and rollovers. On September 14, 2006, the agency announced its proposal to make this technology standard equipment on all light-duty passenger vehicles starting with MY 2009 vehicles.
- Lane Departure Avoidance – These are systems that track vehicle position within a lane and use this information to warn and/or provide steering assist to help a driver maintain vehicle position within the lane, consequently helping to prevent run-off-the road crashes. These are commonly referred to as Lane Departure Warning and Lane Keeping Assist systems. This is emerging technology offered on some vehicle models. Examples of these technologies have been the subject of field operational tests and have been shown to be effective in reducing the number of relevant crashes.²⁰
- Rear-End Collision Avoidance – These are systems that have forward vehicle detection capability and use this information to warn the driver and/or automatically brake to prevent rear end crashes. This is an emerging technology with a variety of systems with

²⁰ Road Departure Warning System Field Operational Test: Methodology and Results, Volume 1: Technical Report, April 2006. http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/RDCW-Final-Report-Vol.1_JUNE.pdf

varying capabilities currently available on some vehicle models. These technologies have been the subject of field operational tests.²¹

Approaches for encouraging crash avoidance technologies:

NHTSA believes an iterative or phased approach for incorporating crash avoidance technologies into NCAP would yield beneficial safety results and would provide additional information to consumers that would generate market demand. In the near term, NCAP would begin promoting the three priority crash avoidance safety technologies listed previously. Based on NHTSA specified definitional and/or performance requirements, manufacturers would “self-certify” (similar to what is currently being done for side air bags and the completion of out-of-position testing) that some or all of their vehicles contained those selected safety technologies. The agency would then highlight to consumers which vehicles have the technology.

The agency also plans to investigate the feasibility of developing a separate crash avoidance rating. The agency is currently considering two different approaches for generating such a rating. For illustrative purposes, an A, B, C rating is hypothesized with A being the highest and C being the lowest.

- Approach #1: Would assign each technology an equal weighting of one letter grade. For example, if a vehicle had only one technology it would receive a C but one vehicle that had all three recommended technologies and would receive an A.
- Approach #2: Would individually weight the technologies according to their anticipated target population and their anticipated effectiveness. The agency would have to develop a new rating system that assigned points to each technology and develop a rating scale that had specific point values for each rating point (i.e. 90-100 points would be an A). Essentially, this means that each technology would be given a point value and as a result some may be weighted higher than others. For example, a vehicle equipped with ESC might receive a B rating versus another vehicle equipped with only lane departure avoidance might receive a C rating. The methodology will be discussed later in this report.

As the technologies evolve and as the agency develops (through its research) more information related to their safety potential, a safety score (i.e. star rating) could then be developed. These scores would apply to technologies whose safety effectiveness had been sufficiently validated through research, field testing, or on-road experience. The agency would need to ensure that it had sufficient data and that there were meaningful distinctions between different types of technology. After such an analysis, a set of performance tests could be developed that would be able to distinguish a range of performance.

This approach could later be expanded into a performance-based crash avoidance rating program comprised of a series of tests that correlate to the crash problem areas shown in Table 6. As commercial systems are offered that address all four crash problems, performance-based ratings

²¹ Evaluation of an Automotive Rear-End Collision Avoidance System. <http://www-nrd.nhtsa.dot.gov/pdf/nrd-12/HS910569.pdf>

for them could be added. Overall vehicle crash avoidance capability to address specific safety problems would be assessed, as opposed to individual technologies.

In addition to crash avoidance technologies, the agency notes that there are additional technologies that may have the potential to reduce the harm inflicted before, during, and after a crash. These technologies include: imminent crash braking, automatic seat position adjust, automatic head restraint adjust, and advanced adaptive restraints. Accordingly, the agency plans to monitor the research and deployment of such technologies to determine their potential safety benefits and if NCAP can be used to accelerate their deployment, when appropriate.

Enhance the Presentation and Dissemination of Safety Information

Combined safety score

Description of issue

Several research reports have indicated a need to pursue a summary safety rating. In their *Special Report 248, Shopping for Safety: Providing Consumer Automotive Safety Information* (1996), the Transportation Research Board (TRB) recommended that NHTSA develop a summary safety rating that includes both crash avoidance and crash performance information. TRB recognized the potential for consumers to become inundated with vehicle safety information – particularly as new tests are designed and new safety features are introduced into vehicles.

In its April 2005 report, *Opportunities Exist to Enhance NHTSA's New Car Assessment Program* (p. 52), GAO commented that NHTSA “could provide summary ratings” and “present information in a comparative manner,” although no specific approaches or methodologies were given. The report went on to say that, “*Consumer Reports, The Car Book, the Insurance Institute, and all of the other NCAP's provide more summary information for consumers than NHTSA*” but mentioned that, “NHTSA and IIHS did not develop an overall crashworthiness rating because combining ratings is technically difficult and could obscure low ratings in one test area that would be revealed when test results are reported separately.”

Recent NHTSA-sponsored consumer research (March 2006, *The Role of Safety in Recent Vehicle Purchases*) looked at how consumers utilize crash test information when purchasing a new vehicle.²² As part of that research, NHTSA asked participants who were familiar with star ratings some basic questions about a summary rating. In general, the participants saw the value in providing a summary rating (i.e., they wouldn't have to worry about how to weigh all the different star ratings, and, in theory, it would make comparing vehicles easier). The participants did, however, have some reservations if the next level of detail was not readily available or if important information was obscured by the summary rating. Intuitive web design and page layout will be critical factors in allaying these concerns so that consumers who want the detailed information can easily find it and understand how individual test results have been combined.

²² Docket No. NHTSA-2004-19104

Other consumer information programs such as the IIHS, Japan NCAP, and Euro NCAP have developed summary ratings that combine their respective crashworthiness readings. More recently, the IIHS has implemented another rating system that incorporated an ESC criterion. Additionally, recent publications from consumer groups such as Consumer Reports and www.informedforlife.org have combined safety ratings not only from NHTSA but also from the IIHS.

Approaches to enhancing the presentation of NCAP Ratings

Based on current consumer demand for simplified useful information, the agency will implement a summary crash rating as a short term enhancement and transition to one overall rating that combines crashworthiness and crash avoidance star ratings. For the near term, classification of appropriate test anomalies, or “safety concerns,” would still be presented as they are now.

The agency would focus first on combining the frontal and side crashworthiness ratings using weighting factors compiled from NASS data. This method would combine the frontal ratings for driver and right front passenger seating positions with the side ratings for the front and rear passenger seating positions into *one crashworthiness rating* and leave NHTSA’s current rollover rating separate. The following summary crashworthiness rating concepts are examples of potential methods for combining vehicle crash information. It should be noted that the weightings would vary depending on the injury level chosen and could be re-evaluated as the NASS data was updated. Two approaches being considered are presented below.

- Approach # 1: The overall frontal crash rating would combine the driver and right front passenger into a single star rating by averaging the two seating positions together. The same would be done for the dummies in the side crash to compute the overall side crash rating. To compute the overall crashworthiness rating, the overall frontal and the overall side impact performance would be combined by using weighting factors obtained from the NASS. Each individual total (overall front and overall side) would be weighted by that crash mode’s contribution to the total fatalities occurring in the real world. For example, because there are many more frontal crashes than side crashes that lead to fatalities, the combined frontal score would be more heavily weighted than the overall side score.
- Approach #2: For each individual crash mode (front and side), this method would normalize each IARV that NHTSA included in the rating by established IARVs for that dummy, body region, and crash mode. Using the NASS data, these normalized values would then be multiplied by the occurrence of that injury in the real world. Body injury regions that are coded by NASS but are not measured by the dummy and or not selected by NHTSA for inclusion in the rating would be equally distributed among the remaining body regions. With this methodology, NHTSA would have to determine the levels that correspond to the various star ratings.

As discussed earlier in the “Encourage the Implementation and Use of Crash Avoidance Technologies” section of this report, a separate, advanced *crash avoidance technology star*

rating is premature at this point because the agency has not yet determined how to incorporate the risk of avoiding the crash into a metric that could be measured on a continuous scale. However, a future overall summary rating would attempt to combine all front, side, and rollover ratings with the recommended safety technologies. This type of summary rating system would result in a point-based system where, for example, the maximum point value that any vehicle could receive would be 100 points. In this illustration, a vehicle might receive up to 90 points for its performance in NCAP tests (currently front, side and rollover). The vehicle's other 10 points could be determined by the vehicle features NHTSA deems as "recommended." Again, with this methodology, NHTSA would have to determine the levels that correspond to the various star ratings.

Presentation of Safety Information

As NCAP and use of the World Wide Web has grown, so has the need to consolidate and better present vehicle safety information to consumers on www.safercar.gov.

Approaches to enhancing the presentation of Vehicle Safety Information

- **Develop other topical areas under *Equipment and Safety* section of safercar.gov.** These areas could include those systems for which NCAP ratings are not developed but for which there is consumer interest. These would include such things as braking, lighting, safety belt reminder systems, and technologies whose benefits and safety impact are not fully established for rating purposes.
- **Redesign the site to improve organization.** Because the safercar.gov site has grown, there is a need to re-evaluate the front page (of www.safercar.gov) and to re-organize some of the information, particularly much of the information contained under the "Resources" header.
- **Improve the search capabilities on the website.** With the large amount of information in the NCAP database, flexible and fast searching via safercar.gov is critical. NHTSA will look at improving the speed and flexibility of the search through the introduction of both advanced search programming and the introduction of new search features. Common search feature requests to the agency include allowing consumers to search by a selected vehicle technology or by a minimum star rating level.
- **Combine recall, ratings, and insurance information.** With a simple make-model-year search, make it possible for consumers to get all relevant NHTSA information – all NCAP ratings, all complaint, investigations, recall information, and insurance information (from the Highway Loss Data Institute) – on one summary web page. Some commercial sites are already attempting to do this and have had positive feedback from the general public.

V. Other Areas

Child Restraints: A NHTSA-sponsored study on Lower Anchors and Top Tether for Children (LATCH) use and misuse in the field indicated that consumers prefer using LATCH to seatbelts for installation of child restraints. Similarly, when the agency developed the Ease of Use program, the LATCH technology was just emerging. In light of this, the agency is examining potential changes to its Ease of Use (EOU) ratings programs for Child Restraint Systems (CRS) that would highlight easier-to-use versions of this hardware for consumers. The agency is also taking a look at enhancing the CRS labeling and instructions rating criteria that is already assessed by the EOU labels in an effort to continue encouraging their improvement. Concurrent with this EOU research, NHTSA has been monitoring the progress of a technical working group formed by the International Standards Organization (ISO) which is developing a system to rate the CRS-vehicle interface and will take this into consideration. Finally, the agency is also examining whether additional vehicle-related information (such as the number and locations of lower anchors in vehicles) on the safercar.gov website and the *Buying a Safer Car for Child Passengers* brochure would prove useful to consumers.

Pedestrian: Both Euro NCAP and Japan NCAP currently have a pedestrian rating program in addition to vehicle ratings. In 2004, there were 4,641 pedestrian deaths and 68,000 pedestrian injuries.²³ While we have not conducted consumer research in this area to determine consumer interest in such a rating, the agency did consider the possibility of a pedestrian rating for NCAP. However, NHTSA is currently participating in the development of a Global Technical Regulation (GTR) on pedestrian protection and given the intent of the GTR (to establish global regulations), the agency decided it was premature at this time to consider a pedestrian test for NCAP in lieu of the current international regulatory activity on this subject.

Braking: NHTSA has performed and evaluated stopping distance tests for passenger vehicles. In parallel, the agency has also been examining the real world data for potential benefits of having shorter stopping distances. While the test results have indicated that there is a disparity between vehicle classes (i.e., passenger cars, vans, and sport utility vehicles), the real world data was unable to quantify the benefits. Therefore, the agency is not pursuing a rating program that rates vehicles on braking performance at this time.

Lighting: The agency has evaluated the rating of headlamp performance for vehicles. While NHTSA will continue to study headlamp performance, the agency is not considering a ratings program at this time. We have made this decision in keeping with the philosophy that our NCAP ratings should be able to quantify safety improvements. We have found that this is not currently possible in the lighting area for two reasons. First, NHTSA has found that there is a lack of objective data available to adequately quantify the safety benefits that would occur as a result of such a program. Also, the agency has found a potential negative result from a headlamp rating system. For example, while improved ratings could be achieved by solely raising the height of the headlamps, thereby giving a longer field of illumination, the result may be undesirable glare to oncoming drivers.

²³ 2004 NHTSA Traffic Safety Facts

VI. Additional areas not considered

Frontal: A new test to address injuries and fatalities to occupants of vehicles striking narrow objects could be conceived by using the FMVSS No. 201 side impact pole or developing a new pole to mimic these types of frontal impacts occurring in the real world. In its response to the agency's notice seeking comment on changes to frontal NCAP, the IIHS submitted comments in support of a frontal pole test. The agency is also aware that the IIHS is currently conducting research in this area as a potential new consumer metric program. Because there is no existing test procedure to conduct such a test and the agency has not conducted the necessary work to support such a program, the agency is not pursuing this test as an approach to enhance frontal NCAP at this time.

Rollover: Occupant protection in rollover crashes were recommended by the GAO as being areas where a consumer information program could be initiated. The agency is actively engaged in SAFETEA-LU mandated rulemaking to address occupant protection in rollover crashes from both a roof crush and ejection mitigation perspective. However, the research to support the rulemaking activity has not yet been completed and therefore, they were considered premature for inclusion in NCAP at this time.

Front-to-Front compatibility: In June 2003, NHTSA published and identified some initiatives to address both front-to-front and front-to-side vehicle compatibility in a report, "Initiatives to Address Compatibility." Similarly, although no metrics were outlined, the GAO in its review of NCAP suggested that the interactions between large and small vehicles would be one area for the agency to develop approaches to enhance its NCAP activities. Since the NHTSA and subsequent GAO report, the agency has been conducting a program to assess the viability of several potential frontal crash compatibility metrics. Unfortunately, the results to date have not been successful in identifying metrics correlated to real-world safety that could be measured in crash tests. As such, further research and development, both by NHTSA and international vehicle safety testing organizations, is being conducted in an attempt to identify viable compatibility metrics. Because there exists no viable compatibility metric at this time, the agency considers a compatibility NCAP rating program premature.

VII. Conclusion

The agency's NCAP has been successful in improving safety. The approaches outlined in this report provide an analytic basis for initiating stakeholder dialogue for upgrading the NCAP. The program needs to be updated to reflect changes in safety technologies, the automotive fleet, and the safety problems that can be affected by this type of program. Research into current real world problems and consumer safety preferences for information indicates that the program can be improved by the promotion of promising crash avoidance technologies, the addition of new injury criteria, the incorporation of more advanced anthropomorphic test devices, new tests, and the consolidation of ratings information.

Appendix A: Determination of Pre-Crash Scenario Typology

The information in Table 6 is based on a methodology authored by the Volpe Center.

In this methodology, a new pre-crash scenario typology for crash avoidance research is based on the General Estimates System crash database. This new typology consists of 36 pre-crash scenarios that precede all police-reported crashes involving at least one light vehicle (i.e., passenger car, sports utility vehicle, van, mini-van, and light truck).

Each of the 36 scenarios can be mapped to one of the crash types listed in Figure 5. For example, 5 of the 36 scenarios are “rear-end crash scenarios” in that they are scenarios that lead to rear-end crashes. Similarly, other subsets of the 36 scenarios map to run-off-road, lane change, and crossing path crashes.

Each scenario has detailed information associated with it including estimated number of persons involved in a particular scenario as well as the proportion of maximum AIS (MAIS) 0-6 injuries. Using this information the total amount of MAIS 3+ injuries can be calculated for each scenario, and by adding all relevant scenarios of each crash type, total MAIS 3+ injuries for each crash type can be estimated.

Example: Calculation for rear-end crashes

5 pre-crash scenarios are defined as leading to rear-end crashes. They are: lead vehicle stopped (rear-end crash scenario 1), lead vehicle decelerating (scenario 2), lead vehicle moving at lower constant speed (scenario 3), following vehicle making a maneuver and approaching a lead vehicle (scenario 4), and following vehicle approaching an accelerating lead vehicle (scenario 5).

Rear-End Scenarios	Persons Involved	MAIS INJURY PERCENTAGES				% MAIS 3+	Estimated
		% Serious	% Severe	% Critical	% Fatal		MAIS 3+ injuries
Scenario 1	3,032,000	0.42	0.04	0.02	0.02	0.50	15281
Scenario 2	1,283,000	0.41	0.04	0.02	0.03	0.49	6338
Scenario 3	612,000	0.53	0.06	0.03	0.10	0.71	4357
Scenario 4	249,000	0.42	0.05	0.02	0.01	0.50	1245
Scenario 5	54,000	0.46	0.05	0.03	0.01	0.55	296
Total MAIS 3+*							28000

* Total MAIS 3+ injury estimate is rounded to the nearest thousand injuries

As shown, this approach resulted in an estimate of 28,000 MAIS 3+ injuries for rear-end crashes. Similarly, MAIS 3+ estimates were calculated for each of the remaining crash types as shown in Table 6.