THE U.S. NEW CAR ASSESSMENT PROGRAM (NCAP): PAST, PRESENT AND FUTURE

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ABSTRACT

The New Car Assessment Program (NCAP) tests and results provide crucial information to consumers on the relative safety of new vehicles. The expanded visibility and use of NCAP information by consumers in their buying decisions, and increased references to NCAP information by vehicle manufacturers in their advertisements, contribute to the manufacture and purchase of safer vehicles and attest to the expanded importance of NCAP. NHTSA has increased the types of tests and the categories and numbers of vehicles it tests and is considering the use of smaller stature dummies in NCAP. Developmental testing has been conducted and consideration is being given to adding crash avoidance information, such as braking and headlamp performance, as well as child restraint ratings, to NCAP. A fully developed plan for the future of NCAP will assure its maximum safety benefits and cost effectiveness. This paper reviews NHTSA's NCAP program, including its history and present status, with a reference comparison to NCAP programs of other organizations in the U.S. and abroad. It discusses NCAP in relation to rulemaking. It examines NCAP's future prospects, including changes and additions to its testing program and the presentation of its information, international harmonization, program management, and strategic issues.

INTRODUCTION

The annual death toll on America's highways has dropped from more than 50,000 to about 40,000 over the past two decades. One factor contributing to this decline is the increased attention consumers pay to safety when purchasing new vehicles. A prime source of vehicle safety information is NCAP, a rating and information program conducted by the U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA). NCAP was designed to provide safety information to the public and to improve occupant safety by providing market incentives for vehicle manufacturers to voluntarily design better crashworthiness into their vehicles.

U.S. NCAP HISTORY

NCAP was mandated under Title II of the Motor Vehicle Information and Cost Savings Act of 1973 (15 U.S.C. §1942 et seq.) to provide information to consumers on the relative crashworthiness of automobiles. NHTSA began assessing the occupant protection capabilities of new cars in 1978 by conducting frontal barrier crash tests at a high speed. The first goal of NCAP was to give consumers a measure of the relative safety potential of automobiles. The second goal was to establish market forces to encourage vehicle manufacturers to design higher levels of safety into their vehicles.

NCAP began crash testing light trucks with the 1983 model year. NHTSA began an NCAP Optional Test Program in 1986, in which manufacturers could request a test or retest of a particular model based on design changes or the introduction of innovative safety features. The manufacturer pays the cost of this test, which NHTSA controls at an approved test site. In 1994, NHTSA changed from reporting test results in a technical, numerical format to an easy-to-understand five-star rating system. In 1997, the agency began its crash test program for side impact. The combination of frontal and side crash tests in NCAP gives consumers relative safety information on the two most common injury-causing crash events–frontal and side impacts. Most recently, in January 2001, NHTSA announced its Static Stability Factor (SSF) ratings program and published the first results of its new rollover resistance ratings, which covered 43 model year (MY) 2001 vehicles. In February 2001 an additional 34 ratings were published.

TEST PROCEDURES

NHTSA chooses crash test vehicles from passenger car, light truck, sport utility vehicle, and van models that are new, potentially popular (such as the PT Cruiser), redesigned with structural changes, or have improved safety equipment, such as an air bag. The vehicles are bought from new car dealers' lots and are not supplied by the manufacturer. One of each model

is tested. NHTSA uses four contractors to conduct its NCAP testing.

Crash test results on models that have no basic changes are carried over to the next year, so results are available on about 85 percent of the new cars sold. NCAP restrains test dummies within the vehicle with all manual and automatic restraints to assess the vehicles' maximum crashworthiness, whereas compliance tests use only passive restraints (automatic belts and air bags). NCAP results do not apply to unbelted occupants. All passive restraints available on a vehicle (such as air bags) are kept operational in the tests.

Crash Testing for Frontal Collisions

Vehicles with Hybrid III 50th percentile adult male dummies in driver and front passenger seats are crashed into a fixed barrier at 56.3 kilometers per hour (km/h) (35 miles per hour (mph)). This impact is equivalent to a vehicle moving at 112.7 km/h (70 mph) striking an identical parked vehicle, or equivalent to two identical vehicles each moving toward each other at 56.3 km/h (35 mph). NHTSA collects data on injury potential in both NCAP and compliance tests by measuring accelerations and forces placed on an occupant's head, chest, and upper leg. The lower the numbers for the head, chest, and the femur load, the lower the potential for injury.

Between 1979 and 1990, NCAP used only Hybrid II dummies. Starting with MY 1990, NCAP tests were conducted with the test dummy the vehicle manufacturer used to certify compliance to FMVSS No. 208, and starting with MY 1992, NCAP tests were conducted using the dummy that the manufacturer recommended for the higher severity testing, regardless of the dummy used in certifying compliance to FMVSS No. 208. Switching to exclusive use of the Hybrid III dummy has permitted the collection of more injury data, which enables NHTSA and manufacturers to obtain research data on the potential for injury to other body parts. Using the Hybrid III exclusively also eliminates potential performance variability.

The head injury criterion (HIC) represents the likelihood of skull fractures and/or brain injury, with a maximum allowable value of 1,000. Severe injuries to the chest, including damage to the lungs, torn aortas, or massive collapse of the rib structure, are measured using either chest acceleration in g's (acceleration due to gravity), with the maximum allowable level of 60 g's over 3 milliseconds, or chest compression, with a maximum reduction of three inches in the distance between the sternum and spinal column. Femur load measures the compressive force transmitted axially through the upper legs, with a maximum allowable level of 2,250 pounds of force. NHTSA concluded that a combined effect of injury to the head and/or chest should be used, since it is well documented that an individual who suffers multiple injuries has a higher risk of permanent disability or death.

Vehicles in NCAP crash tests at 56.3 km/h (35 mph) experience a change in velocity, including rebounding from the barrier, of approximately 64 km/h (40 mph), whereas the change in velocity for 48.3 km/h (30 mph) crashes is approximately 53 km/h (33 mph). Compared to the 48.3 km/h (30 mph) FMVSS No. 208 compliance tests, the 8 km/h (5 mph) faster NCAP crash tests produce a 36-percent increase in crash energy. A primary reason for testing at the higher speed is that little crashworthiness difference exists between vehicles for restrained occupants in crashes with changes in velocity below the FMVSS No. 208 test speed. Raising the speed to 56.3 km/h (35 mph) enables us to more easily distinguish any crashworthiness differences.

Compared to the compliance testing for FMVSS No. 208 test crashes, the higher severity NCAP crashes cause increased intrusion and higher acceleration in the occupant compartment. The NCAP crash tests may cause significant erratic motion and deformation to the steering assembly, instrument panel, and floorpan. Also, the more severe NCAP tests may also approach or exceed the protective limits of some safety belt systems, and the greater belt stretch and "spool out" may allow excessive dummy travel.

Since the test simulates a crash between two identical vehicles, consumers are cautioned to only compare vehicles from the same weight class when comparing frontal crash protection ratings. The rating indicates a belted person's chances of incurring an injury serious enough to require immediate hospitalization or to be life threatening in the event of a crash.

Originally, NCAP reported the actual HIC, chest acceleration and femur load scores with a disclaimer that only vehicles within 500 pounds of each other could be compared. NHTSA reported the test scores along with a graphic representation intended to show the vehicle's relative rank in its category. NHTSA

analyzed the system, especially the implied precision of the published test scores, and found that it was confusing to consumers. In response to 1992 Senate Appropriations Committee requirements, NHTSA performed a use study and in 1994 began implementing new methods of informing consumers of the comparative levels of the safety of vehicles through NCAP.

These new star ratings were designed to give consumers a quick, simplified single point of comparison between different vehicles. The star scale was based on a "Level of Protection Scale," which NHTSA developed to relate the probability of sustaining an injury to the level of protection from injury that a vehicle provides its occupants. NHTSA mathematically combines the head and chest injury measurements and produces a rating of one to five stars, with five stars indicating the relatively highest level of protection within the vehicle's weight class.

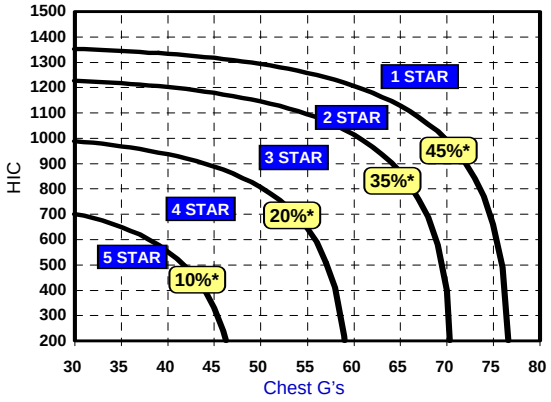
★★★★★ = 10% or less chance of serious injury
★★★★ = 11% to 20% chance of serious injury
★★★ = 21% to 35% chance of serious injury
★★ = 36% to 45% chance of serious injury
★ = 46% or greater chance of serious injury

Although it is impossible to assess how well a vehicle provides protection in all circumstances using a single test, NCAP ratings provide a useful basis for comparing the relative crash safety of vehicles within each class or grouping.

Since 1996, Japan NCAP has conducted the same full frontal crash test program as the U.S. NCAP. However, Japan NCAP uses a letter category rating system (A/B/C/D) based on head injury criterion and chest acceleration, and it has further split the A category into A, AA and AAA levels to further discriminate vehicle safety performance. For frontal collisions, Japan NCAP rates injury risk to drivers and passengers, plus door open-ability, rescuability and fuel leakage. In the 1990s, Australian NCAP issued combined ratings based on full frontal and offset frontal tests, but in 1999 it dropped the full frontal test.

The relationship of the star rating system to injury probability and to the range of HIC and chest G values is shown in Table 1.

Table 1.
Relationship of the Star Rating and Severe Injury Probability to HIC and Chest G



Crash Testing for Side Collisions

In the past twenty years, car structures have been optimized for the most frequent crashes, the frontal crash. After frontal crashes, side impacts are the most serious type of automobile crashes causing injury and death. Though only one in four crashes is a side impact, more than one-third of seriously injured occupants sustained their injuries from vehicle side impacts.

NHTSA implemented a dynamic side impact compliance test, FMVSS No. 214, in 1990. It simulates a 90 degree side impact, in which a moving deformable barrier, representing the striking vehicle, moves at 53.9 km/h (33.5 mph), crabbed at 27 degrees, into the stationary struck vehicle. NHTSA began testing passenger cars in side impact in NCAP in 1997. In the USA NCAP side impact, the striking vehicle is towed at an 8 km/h (5 mph) higher speed than in the compliance test.

For side collisions, testing represents an intersection-type collision with a 1,367.6 kilogram (3,015 pound) nominal weight deformable barrier moving at 62 km/h (38.5 mph) into a standing vehicle. Side collision star ratings indicate the chance of a life threatening chest injury for the driver and the left rear seat passenger. If the pelvic instrumentation in the crash test dummy indicates a high likelihood of pelvic injury in the lateral test, the consumer is also informed of this possible injury. Head injury is not measured in these tests. Since all tested vehicles are impacted by the

same size barrier, it is possible to compare side crash results from vehicles from different weight classes.

★★★★★ = 5% or less chance of serious injury
★★★★ = 6% to 10% chance of serious injury
★★★ = 11% to 20% chance of serious injury
★★ = 21% to 25% chance of serious injury
★= 26% or greater chance of serious injury

It should be noted that some SUVs tipped over when struck during side impact collision testing. Since the test was not designed to measure how likely a vehicle is to rollover, NHTSA makes no prediction whether those vehicles are more prone to rollover in side impact crashes than other SUV models. Nonetheless, the tests do reinforce real-world crash experience that shows that, when struck in a side impact collision, SUVs are more prone to roll over than other vehicle types. It should be noted that the vast majority of rollovers do not occur during side impact collisions. Most rollovers occur when a single vehicle runs off the road and is tripped by a curb, ditch, or other object or surface.

Other NCAPs also perform side impact tests. Euro NCAP rates vehicles on both side impact and side pole impact (to rate head protection). Japan NCAP rates side impacts using a rating system with A/B/C/D categories, and the A category has one subcategory, A★, which indicates vehicles with especially good crash test injury scores. The side crash ratings cover injury risk to drivers, door open-ability, driver rescuability, and fuel leakage. Australian NCAP also rates side impact protection, performing its side impact test into a deformable barrier at 50 km/h (31 mph). Lastly, in the United States, the Insurance Institute for Highway Safety (IIHS) conducts front-to-side and side pole impact tests as part of its crash test program.

Rollover Resistance Ratings

There are approximately 233,000 light vehicles involved in rollover crashes, with 10,000 fatalities, annually. Over 60 percent of SUV fatalities occur in rollover crashes. In December 1998, NHTSA decided to develop consumer information on rollover resistance via NCAP. From 1991 to 1999, NHTSA studied both static metrics and vehicle maneuver (dynamic) tests for their potential to describe rollover resistance in an objective and repeatable way.

Following publication of the results of the most recent driving maneuver test program in 1999, NHTSA decided to use the static stability factor (SSF) as the basis for a rating system. SSF was chosen over vehicle maneuver tests because SSF is a good measurement for both tripped and untripped rollover (95% and 5% of the rollover problem respectively), while dynamic maneuver tests only relate to untripped rollover. Tripped rollover occurs when a vehicle's wheels hit a curb, soft shoulder or other roadway object, whereas untripped rollover is caused by driving maneuvers (entering a curve at excess speed, e.g.) – rather than wheel contact with a tripping object.

Improvements in SSF improve both types of rollover risk, whereas it is possible to make vehicle adjustments that improve performance in a dynamic maneuver test but have no positive impact on the risk of tripped rollover. Other reasons for selecting the SSF measure are: maneuver test results are greatly influenced by SSF; the SSF is highly correlated with actual crash statistics; it can be measured accurately and explained to consumers; and changes in vehicles to improve SSF are unlikely to degrade other safety attributes.

NHTSA published a Request for Comments in June 2000 on the use of the SSF for a 5-star rating program on the rollover resistance of light vehicles. In the conference report on the FY2001 DOT Appropriation Act, Congress permitted NHTSA to move forward with the rollover rating proposal while calling for a National Academy of Sciences study by summer 2001 to assess the validity of SSF as a rollover metric and to compare SSF versus dynamic tests. A January 2001 notice [49 CFR Part 575, which can be found on NHTSA's web site at http://www.nhtsa.dot.gov/cars/rules/rulings/roll_resistance/] responded to technical comments and announced the agency's intent to use the SSF as a measure, and published the initial SSF ratings.

These ratings measure the risk of rolling over in a single vehicle crash which, in most cases, occurs when the vehicle runs off the road. The ratings do not predict the likelihood of this type of crash occurring. The lowest rated vehicles (1-star) are at least four times more likely to roll over than the highest rated vehicles (5-stars) in a rollover situation. When NHTSA compared ratings based on the SSF to 220,000 actual single vehicle crashes, not only did they relate very closely to the real-world rollover experience of vehicles, they also showed that taller, narrower vehicles, such as sport utility vehicles (SUVs), are more likely than lower, wider vehicles,

such as passenger cars, to trip and roll over once they leave the roadway. Accordingly, NHTSA awards more stars to wider and/or lower vehicles.

★★★★★ = risk of rollover of less than 10 %
★★★★ = risk of rollover 10 to 19 %
★★★ = risk of rollover 20 to 29%
★★ = risk of rollover 30 to 39%
★ = risk of rollover greater than 40%

Most rollovers occur when a vehicle runs off the road and strikes a surface or object that "trips" it. Electronic Stability Control (ESC) (which is offered under various trade names) is designed to assist drivers in maintaining control of their vehicles during extreme steering maneuvers. It senses when a vehicle is starting to spin out (oversteer) or plow out (understeer), and it turns the vehicle to the appropriate heading by automatically applying the brake at one or more wheels. Some systems also automatically slow the vehicle with further brake and throttle intervention. ESC has the potential to help drivers avoid running off the road and having a single vehicle crash in the first place. However, ESC cannot keep a vehicle on the road if its speed is simply too great for the available traction and the maneuver the driver is attempting, or if road departure is a result of driver inattention. In these cases, a single vehicle crash will happen, and the rollover resistance rating will apply as it does to all vehicles in the event of a single vehicle crash. Some of the 2001 model year vehicles that will be rated have ESC and are identified in the charts with the rollover resistance ratings.

NHTSA expects to issue rollover resistance ratings for more than 80 MY 2001 vehicles by April 2001. At present, only the U.S. NCAP program issues rollover resistance ratings.

NCAP PROVIDES OTHER SAFETY INFORMATION

In addition to providing crash test data, NCAP also provides safety features charts on its Internet web site and in its publications that indicate which of the following safety features are found on listed vehicles:

- Seat Belts: adjustable upper belts, seat belt pretensioner, energy management features, integrated seat belt systems, rear center seat lap/shoulder belts;
- Air Bags: advanced air bags, side air bags;
- Child Seat Attachment System: lower anchorages, per NHTSA's new standardized child safety seat system;
- Head Injury Protection: whether, by means of padding or head air bags, the vehicle meets new head injury protection standards fully implemented by 2003;
- Head Restraints: dynamic head restraints and rear seat head restraints, and whether the rear restraints meet the same size and strength requirements as front seat head restraints;
- Anti-lock Brake Systems: vehicles with four-wheel ABS are indicated. The charts indicate ABS systems with Brake Assist.

NCAP also lists the following additional safety-related equipment and their availability in vehicles: traction control, all-wheel drive, electronic stability control, automatic-dimming rearview mirrors, and daytime running lights.

GETTING THE INFORMATION TO CONSUMERS

To effectively disseminate NCAP safety information, NHTSA distributes NCAP scores via press release to more than 1,000 organizations, including news services, consumer groups, magazines, and other organizations, with readership in the tens of millions. Among the prominent avenues for this dissemination are *Consumer Reports*, published by Consumers Union, *The Car Book*, now published by the Consumer Federation of America, and *The Car Guide*, published by the United States Automotive Association (USAA).

The 1996 National Academy of Sciences study, *Shopping for Safety: Providing Consumer Automotive Safety Information*, recommended ways to improve automobile safety information for consumers. NHTSA used these recommendations as the basis for several consumer information initiatives. A newly created Consumer Automotive Safety Information Division undertook activities in three major categories: Better Understand Customers and Their Needs; Develop New Information of Value To Consumers; and Improve Customer Awareness and Use of Consumer Information.

NHTSA conducted research and focus groups to determine what information consumers wanted and how best to deliver it. It then developed a general marketing plan to identify target audiences, recommend strategies to improve the dissemination of

consumer information, recommend marketing activities to motivate consumers to seek information, and methods to evaluate the effectiveness of the marketing plan.

NHTSA has taken several steps to improve the comprehensibility and accessibility of NCAP information provided to consumers. Originally, NCAP test information had been presented in technical terms such as a "Head Injury Criteria" value. To improve consumers' understanding of the information, the test results for each vehicle are now presented in an easier-to-understand five-star rating system. In addition, the program now promotes and disseminates NCAP safety ratings to the public through a multifaceted approach of consumer information materials and campaigns, not just through a press release.

Beginning with MY 1995 vehicles, NHTSA has published the *Buying a Safer Car* brochure. The brochure contains NCAP crash test results and safety feature information for new motor vehicles. Building on the success of that publication, NHTSA began publishing another brochure, *Buying a Safer Car for Child Passengers*, that informs consumers on the hazards that air bags present to children and provides advice on other vehicle features that can increase the safety of children in vehicles.

NHTSA has successfully leveraged its limited resources by established partnerships with several organizations to develop and disseminate NCAP safety ratings and other information through its brochures and other materials. In 1998 and 1999 NHTSA developed consumer information campaigns that produced a video news release (VNR), radio public service announcements (PSAs), and three brochures. These products received widespread coverage. NHTSA targeted the population segments most interested in and receptive to information on new car safety.

Increasingly, consumers have gained access to NCAP data via NHTSA's Hot Line and the Internet web site (www.nhtsa.dot.gov). From July 1996 to the present, the number of weekly visitors to the NCAP web site has risen from about 1,000 to 34,000. To date, we have posted NCAP data, brochures, and other consumer motor vehicle safety information on the agency web site. From our web site, consumers can access information on safety problems and issues, testing results for vehicles crash tested in the NCAP program, and theft ratings.

Although NCAP has no mandatory safety performance criteria, industry personnel have expressed the opinion that NCAP has become a defacto regulation in that manufacturers, fearful that consumers would perceive vehicles that got poor NCAP scores to be unsafe, are forced to design their vehicles to perform well at the more demanding NCAP levels than at the established standard levels.

Evidence abounds that NHTSA's efforts have been effective in increasing the public's awareness and use of the crash test ratings in purchasing a new vehicle. Various polls show that more and more consumers are placing a higher emphasis on a vehicle's safety features and performance in making their purchasing decisions. The awareness of this consumer attitude is reflected by the increased references to vehicle model and fleet safety features and performance by the vehicle manufacturers in their advertisements. In some cases, manufacturers actually cite NCAP results in their advertisements. Manufacturers who once opposed the government's crash test program, now market their "5-star vehicles" to consumers in ads on TV and in magazines.

NCAP has grown into a worldwide force to promote and encourage automotive safety. The original US initiative has led to rapidly developing consumer information programs in Europe, Japan, and Australia.

FUTURE AND POTENTIAL NCAP EXPANSION

The future expansion of NCAP depends on several factors, primarily engineering science and funding. Limited funding levels can restrict NCAP's expansion into new test programs even if research is able to solve scientific obstacles. Funding levels also can restrict the extent to which NCAP can produce safety information and communicate it to the public. Certainly, NHTSA is proceeding with all haste to get more safety information to more consumers, but reality dictates that priorities will have to be established and followed.

Even for existing tests, funding constraints limit the number of vehicles NCAP can test. Twenty-five percent of the e-mail on the *Buying a Safer Car* web page is from consumers complaining that the vehicles they are interested in have not been tested.

It has been suggested that NCAP could use computer-based simulations for enhanced safety design.

Although costly, simulated crashes allow designers to quickly model multiple crashes at multiple impact points. Manufacturers use computer modeling to simulate frontal, rear, and side impacts and roof crushes. They may model a specific component and in some cases, use nonlinear finite-element models to simulate the entire vehicle and predict its interaction with occupants during a collision. The simulations can provide information on structure deformation, intrusion into the occupant compartment, and the forces generated by structural components. However, computer-simulated crashes are expensive since they require access to a supercomputer, and their use would not eliminate the need for crash tests. While simulation models are good vehicle design tools, their usefulness as a tool for evaluating the relative safety performance of vehicles for consumer information has not been demonstrated.

Small Sized Dummies

A new generation of air bags and further occupant safety advances require more advanced crash test dummies to accurately measure various crash forces imparted to differently sized occupants in different crash situations. As we expand required protections for men, women and children of varying sizes, we will need appropriately sized and instrumented dummies to provide estimates of the severity and extent of injury. In 2000, following several years of research, NHTSA adopted new smaller size Hybrid III dummies - 12 month old, 3 year old, 6 year old, and 5th percentile female dummy - into Part 572, Anthropomorphic Test Devices (49 CFR Part 572). In May 2000, the FMVSS 208 interim final rule for advanced air bags added the new family of crash test dummies to the test requirements of the standard.

Developmental tests using the 5th percentile dummy were performed by NCAP in offset frontal and full frontal crashes in 1997 and 1998. The FY 2001 DOT Appropriations Act prohibits the NCAP program from including this dummy in its test results. The Research and Development Program is continuing to investigate the 5th percentile dummy in NCAP-type tests. When the FMVSS 208 amendments become effective in new production vehicles, NHTSA plans to reevaluate frontal NCAP; including using the 5th percentile dummy and modifying injury criteria. Crash tests with the new child dummies are being conducted as part of the child restraint safety program (see below).

Offset Frontal Crashes

NHTSA's frontal crash standard specifies that the full front of a vehicle impact a rigid barrier. However, according to National Automotive Sampling System (NASS) estimates, 42 percent of frontal crashes are full-frontal crashes and about 56 percent are offset frontal crashes. In September 1996, the U.S. Congress directed NHTSA to conduct a feasibility study toward establishing a Federal Motor Vehicle Safety Standard (FMVSS) for frontal offset crash testing. The offset research and testing is part of NHTSA's actions to develop standards that improve overall vehicle safety in frontal crashes while accommodating international harmonization. In addition, the agency was petitioned to use smaller size dummies to look for aspects of safety that are not evaluated by the traditional 50th percentile male Hybrid III dummy.

Safety experts have noted that lower-extremity trauma is strongly associated with disability. Currently, neither FMVSS No. 208 nor U.S. NCAP assesses injury risks to the lower leg. Results from NHTSA tests in 1999 indicated that the offset test produced a higher potential for lower leg injuries than the flat barrier test. Research suggests that there is a safety value in conducting both the frontal offset test and the flat barrier test. Moreover, the evaluation of the 5th percentile female Hybrid III dummy suggested that the small female could be exposed to higher injury risk than the male dummy in the lower legs and the neck in a frontal crash.

In the United Kingdom, the Transport and Road Research laboratory conducted an investigation based on real-world crashes and found that, despite the use of seat belts, offset frontal impacts pose the greatest threat to car occupants due to vehicle intrusion. The U.K. study suggested that there is a need for a test in which the barrier is offset and a deformable impact face is used.

In response to the Congressional directive, NHTSA studied the offset test (European Union Directive 96/79 EC) at 64.4 km/h (40 mph) to see if that test provides additional benefits beyond the FMVSS No. 208 full frontal barrier test at 48.3 km/h (30 mph). Euro NCAP uses two test contractors and rates vehicle scores on a five star system (Good, Adequate, Marginal, Weak, Poor).

Australia previously studied the EU offset test protocol and found sufficient benefits to offset testing that it adopted an offset frontal test based on the then draft European test standard in 1994 and was the first consumer crash testing program that combined both full frontal and offset crash tests. Starting in 1999, ANCAP aligned its test and assessment procedures with those of Euro NCAP, using a 64.4 km/h (40 mph) impact. ANCAP assigns a score with a maximum of four points to each of four body regions. It modifies the offset score based on modifiers such as excessive rearward movement of the steering wheel, airbag stability, steering column movement, A-pillar movement, structural integrity, hazardous structures in the knee impact area and brake pedal movement. It combines the four body region scores for the offset test, the side test, and these are combined to provide an overall score with a maximum of 32 points. The star rating is based on the overall score. The overall rating considers the deformation of the vehicle's structure and injury measures to the head, neck, chest, and upper and lower legs.

In the U.S., beginning in 1995, the Insurance Institute for Highway Safety (IIHS) initiated a program using a 40 percent overlap frontal-offset test to rate safety in cars. This ongoing frontal-offset testing program evaluates the crashworthiness of new model vehicles crashed at 64.4 km/h (40 mph) into a deformable barrier. The IIHS found that a full-width frontal test and a frontal-offset test complement each other; the full-width test is especially demanding of restraints and the offset test is demanding of the structural integrity of a vehicle. The IIHS rates vehicles either Good, Acceptable, Marginal or Poor based on three factors: structural performance, injury measures, and restraints/dummy kinematics.

Based on real world crash data and laboratory testing of five makes and models, NHTSA's study suggests three changes to frontal testing could yield important benefits. First, the lower leg instrumentation and criteria could be incorporated into both full-frontal and offset-frontal crash testing. Second, the offset-frontal crash test could be used to complement the full-frontal crash test. Third, the small stature dummy could be used in both of the frontal crash tests to evaluate risk to that part of the overall population.

Dynamic Rollover Tests

Some consumer groups and manufacturers have criticized the adequacy of the static stability rating and have urged that NHTSA develop a dynamic rollover test that could, they claim, more accurately predict a vehicle's propensity to roll over.

In 2001, Congress called for the Department of Transportation to fund a study with the National Academy of Sciences on whether the SSF is a scientifically-valid measurement and to include a comparison of the SSF test versus a test based on dynamic driving maneuvers. The study is to be completed in July 2001 with an agency response within 30 days following its completion. In the interim, the Act permits the agency to move forward on its proposal to provide rollover rating information to the public. The Transportation Recall Enhancement, Accountability, and Documentation (TREAD) Act of 2000 requires NHTSA to develop a dynamic rollover test by November 1, 2002. Per the TREAD requirements, NHTSA will develop and carry out a dynamic rollover test program for passenger cars, multipurpose passenger vehicles, and trucks with a gross vehicle weight rating of 10,000 pounds or less. As we develop a rollover test, we will determine how best to disseminate test results to the public.

The key milestones for this provision of TREAD are to obtain public information on measurement approaches and ratings in Spring 2001; publish a notice requesting comments on the proposed test in Fall 2001; publish an announcement of the final test procedure and initial test results in Spring 2002; and initiate full scale MY 2003 tests in October 2002. Building on the agency's 1997-99 driving maneuver testing program, the NHTSA Research and Development program is supporting the TREAD requirement to discriminate the rollover potential of light vehicles by refining the test procedure for the development of a dynamic test. Tests also will be conducted in FY2001 to evaluate electronic stability control devices on light vehicles.

Child Restraint Systems

NHTSA has tasked NCAP to put child restraint systems (CRS) (child safety seats and booster seats) in the frontal and side impact NCAP crash tests for research purposes. NHTSA will seek to enhance the occupant safety for children by examining CRS performance results from some full-scale vehicle testing.

There have been significant gains in child passenger safety since 1975: CRS have saved more than 4,000

children and the occupant fatality rate for children under age 10 dropped 22 percent and is now one-quarter that for the U.S. population as a whole. While the fatality *rate* has decreased steadily, the total *number* of child occupant deaths has not dropped as rapidly, due to concurrent increases in the U.S. child population and a near doubling of the number of miles Americans travel on our nation's highways. In 1999, motor vehicle crashes killed 1,135 child occupants aged 0-10 years in the United States and injured approximately 182,000 children.

Vast CRS performance data can be collected from the NCAP crash testing. In the frontal and side impact NCAP tests, there are spaces for placing two child dummies in a test vehicle for collecting the CRS dynamic performance data (necessitating the removal of the rear adult dummy).

NHTSA has a 3-year-old child dummy for use in frontal crash tests and is developing a 3-year-old child dummy for side crash tests. With instrumented dummies and photographic coverages, HIC, chest G's, neck reading, and dummy's kinematics responses can be collected. Such dynamic test data can be collected from various vehicle makes and models and be used for research purposes.

In preparation of adding CRS to the frontal and the side impact NCAP tests of vehicles equipped with the LATCH system, the NCAP staff is preparing a laboratory test procedure for an NCAP test for CRS, and listing what information NCAP testing can provide to improve the testing of child restraint systems in future FMVSS.

The frontal test with CRS will be conducted first due to the complexity of adding CRS (seating position and availability of dummies) to the side impact test. NHTSA plans to collect data from research and NCAP tests on a total of 34 seating positions in 2001 using 20 vehicles, including 10 with 50% male dummies and 10 with 5% female dummies in the front seat, and Hybrid III three-year-old dummies in the CRS. The in-vehicle testing results for CRS will be used to establish baseline data and as one of the factors evaluated in the feasibility study for establishing an NCAP-like rating system and to aid upgrading future FMVSS.

The TREAD Act contains provisions to improve the safety of child restraints, including minimizing head injuries from side impact collisions. Section 14 of TREAD requires the agency to issue by November 2001 a notice to establish a child restraint safety rating consumer information program to provide practicable, readily understandable, and timely information to consumers for use in making informed decisions in the purchase of child restraints. By November 2002, the agency must establish the child restraint safety rating program and provide other consumer information useful to consumers who purchase child restraint systems.

Among other NCAPs providing comparative CRS information are Euro NCAP and Australian NCAP. Both programs provide results, for each vehicle tested, of child restraints with infant (18 months) and toddler (3 years) dummies in the rear seat for offset frontal and side crash tests. Japan NCAP is working on developing a CRS rating system and test procedure. The IIHS uses 6 & 12-month-old child restraint airbag interaction dummies in its tests.

Braking

The NCAP braking program was conceived as a method of getting additional information about a vehicle prior to its being crash tested in the NCAP. Using the new vehicle models to be crash tested in the NCAP program, NHTSA believes that some comparative crash avoidance information can be obtained. Prior to the crash test, additional tests could be performed on these vehicles without affecting the vehicles' usefulness for NCAP testing. Examples of such information would be comparative information on a vehicle's braking ability or lighting.
In the area of braking, NHTSA is evaluating performance on curves with different peak coefficients of friction, as well as straight-line stopping distances on dry pavement. A series of braking tests on ten light vehicles equipped with four-wheel antilock brakes was conducted during 1998; that report has been released and is on NHTSA's website. A second phase of testing was conducted in late 1999. The second phase was a round-robin test of four light vehicles at three different test sites to compare the braking performance for site variability. The second report is on the NHTSA website as well.

NHTSA's next step will be to publish a Request for Comments notice in the Federal Register, requesting comments on the agency's proposed braking NCAP test procedure and possible reporting methods for consumers. The agency plans to hold a public meeting after the Request for Comments notice has been published. Once we are confident that the test

program is working well, then next year we would start testing vehicles and releasing results.

NHTSA has worked with the Japan Ministry of Transport to draw on its experience with braking NCAP, which it has been doing since 1995. In many respects, the work NHTSA has been doing is close to Japan NCAP's test protocol, such as initial speed and loading condition. NHTSA has independently arrived at similar conclusions with regard to the brake application rate for vehicles equipped with 4-wheel ABS. NHTSA's efforts at this time are to focus on criteria for test facilities including surface friction, water delivery methods, etc.

Lighting

NHTSA sees evidence of potentially significant interest in a lighting NCAP from the ubiquitous automobile magazine articles that discuss the merits or drawbacks of various headlamp beam patterns, and from the many letters of complaint consumers send the agency. Consumers mostly complain about poor performance and glare of headlamps that they use or see.

Headlamp beam patterns, even though required to comply with minimum safety performance requirements, frequently differ in appearance and in actual illumination from one model to another in a myriad of ways and qualities. Providing an objective rating of a vehicle's actual roadway illumination performance would likely be useful to drivers when making vehicle purchase decisions.

NHTSA plans to evaluate industry work to quantitatively assess how pleasing a headlamp beam pattern will be to vehicle purchasers. The addition of this expanded comparative information on vehicles and their headlighting performance would be useful to the American public in its buying decisions. Headlamps that perform well can reduce the stress of nighttime driving. This is becoming more important to the public as the number of older drivers increases. Many vehicle manufacturers are sensitive to the interests of their vehicles' consumers and have developed methods for helping headlamp designers achieve roadway illumination that is pleasing to the customers. Ford Motor Company, in particular, has a methodology that takes drivers' subjective descriptions of beam patterns and converts them to objective, measurable characteristics. The application of such a methodology could be the basis of a new vehicle roadway illumination performance rating system for use by prospective purchasers. NHTSA will consider both high and low beam performance, as well as glare to oncoming drivers, in designing and evaluating a lighting rating system.

As a first step, NCAP proposes to test an array of vehicles prior to crash tests, to evaluate prospective measures for headlighting performance. This assessment is needed to determine if the information discriminates fairly between different levels of lighting performance. The agency awarded a contract to the University of Michigan Transportation Research Institute in September 1999 for the initial phase of this effort. The contractor has completed the first part of the contract and has decided that such a rating system is feasible. The next step is to develop a test procedure for gathering the corresponding data. After testing it, we anticipate being able to collect data for a ratings program on the MY 2003 fleet.

Summary Rating

The 1996 National Academy of Sciences study recommended the development of one overall measure that combines relative importance of crashworthiness and crash avoidance features for a vehicle. The study suggested that 1) vehicle size, 2) laboratory crash test results, 3) expert judgment on the value of engineering features, and 4) real-world crash data for specific models (of limited availability for most, especially new, models) could eventually be incorporated into a single measure that the public could use in vehicle-buying decisions.

While recommending that NHTSA establish a summary crashworthiness rating right away, the study recognized that, for the foreseeable future, summary measures of crashworthiness and crash avoidance must be presented separately due to differences in the current level of knowledge, and differences in the roles of vehicle and driver (skill, behavior) in the two areas. In the interim, the NAS study recommended that the agency develop a summary measure of a vehicle's crashworthiness (combined frontal and side scores) that incorporates quantitative information supplemented with the professional judgment of automotive experts, statisticians, and decision analysts. For crash avoidance, the study recommended the development of a checklist of features for the near future.

NHTSA's developmental work on a summary safety rating includes the evaluation of a number of methodological approaches, including those suggested by interested parties. Real world factors and test results for frontal, side, and rollover ratings are being considered. It is NHTSA's position that basing a summary rating solely on frontal and side crash test results would not provide a complete enough picture of comparative vehicle safety. Recent Congressional action allowing the agency to proceed with its rollover ratings program will enable the agency to move forward with this concept.

Elsewhere in the world, Australian NCAP was the first consumer crash testing program that combined both full frontal and offset crash tests, though it has since changed exclusively to offset frontal testing. Euro NCAP provides a combined frontal/side rating.

CONCLUSION

In 1978, NHTSA began assessing the occupant protection capabilities of new cars by conducting high speed frontal barrier crash tests to support the requirements of the Motor Vehicle Information and Cost Savings Act. It was the first program to provide relative crashworthiness information to consumers on the potential safety performance of passenger vehicles. The program's goals were, and continue to be, to provide consumers with a measure of the relative safety potential of automobiles and to establish market forces which encourage vehicle manufacturers to design higher levels of safety into their vehicles.

NCAP is a dual effort involving both the engineering aspects of research and testing and the communication efforts to determine what kinds of vehicle safety information consumers want and need and how best to convey that information to them.

By all indications, the program has worked. More and more consumers have a heightened awareness of vehicle safety and are placing a higher emphasis on it in their buying decisions. This, in turn, has moved the industry to design cars that perform well in NCAP tests. Numerous studies have correlated improved NCAP performance with reduced fatalities and injuries on the nation's roads. This progress has been repeated around the world, where Australia, Japan, and Europe have developed successful NCAP programs.

NCAP's history has been one of expansion. Initially limited to full frontal crash tests, NCAP now includes side impact tests and rollover resistance ratings. NHTSA is currently undertaking a strategic assessment of further NCAP changes. The U.S. Congress has called for the agency to develop dynamic rollover and child restraint rating systems. Additional ratings may be added for offset frontal crashes, and for braking and lighting performance. Also, a combined crashworthiness rating, or even the feasibility of a combined crashworthiness and crash avoidance rating, may be studied and developed in the future.

Note: The United States Government does not endorse products or manufacturers. Trade or manufacturers' names appear only because they are considered essential to the object of this paper.

REFERENCES

Berkowitz, Alan M. *Comparison of NCAP Frontal Test Driver Star Ratings 1979/80 and 1995/96*. National Highway Traffic Safety Administration, Washington, DC, March 2000.

Case, Michael, RACV, Michael Griffiths, Road Safety Solutions, Jack Haley, NRMA Ltd., Michael Paine, Vehicle Design & Research, *International NCAP Programs in Review.* Paper Number 98-S 11 -O-O3, The 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Windsor, Canada, June 1998.

Chan, Hansun, James R. Hackney, and Richard M. Morgan, National Highway Traffic Safety Administration, and Heather E. Smith, Conrad Technologies, Inc. *An Analysis of NCAP Side Impact Crash Data.* Paper No. 98-S11-O-12, The 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Windsor, Canada, June 1998.

Hackney, James R. *The Effects of FMVSS No. 208 and NCAP on Safety as Determined from Crash Test Results.* 13th ESV Conference. National Highway Traffic Safety Administration, Washington, DC, November 1991.

Highway Safety: Reliability and Validity of DOT Crash Tests. U.S. General Accounting Office, Washington, DC, May 1995.

Kahane, Charles J., James R. Hackney, and Alan M. Berkowitz. *Correlation of NCAP Performance with Fatality Risk in Actual Head-On Collisions*. Report No. DOT HS 808 061. National Highway Traffic Safety Administration, Washington DC, January 1994.

Kurrus, Roger A. and Richard M. Morgan, National Highway Traffic Safety Administration, and Johanna C. Lowrie, Alcosys, Inc. *NHTSA Crash Testing and Safety Information for Consumers*. Seventh International Conference on Product Safety Research, Bethesda, MD, October 1999.

Morgan, Richard M., James R. Hackney, Mary L. Versailles, and Louis Molino, National Highway Traffic Safety Administration, and Johanna C. Lowrie, Conrad Technologies, Inc. *NHTSA Crash Testing and Safety Information for Consumers*. Crash-tech Conference, Munich, Germany, March 1998.

New Car Assessment Program: Response to the NCAP FY 1992 Congressional Requirements. Report to Congress. National Highway Traffic Safety Administration, Washington, DC, December 1993.

Park, Brian T., James R. Hackney, Richard M. Morgan, and Hansun Chan, National Highway Traffic Safety Administration, and Johanna C. Lowrie and Heather E. Devlin, ALCOSYS, Inc. *The New Car Assessment Program: Has It Led to Stiffer Light Trucks and Vans over the Years?* Paper No.1999-01-0064, 1999 SAE International Congress & Exposition, Detroit, MI, March 1999.

Park, Brian T., Richard M. Morgan and James R. Hackney, National Highway Traffic Safety Administration, and Johanna C. Lowrie, Conrad Technologies, Inc. *The Effect of Redesigned Air Bags on Frontal USA NCAP*. Paper Number 98-S11-O-01, The 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Windsor, Canada, June 1998.

Park, Brian T., Richard M. Morgan, James R. Hackney, John Lee, and Sheldon L. Stucki, National Highway Traffic Safety Administration, and Johanna C. Lowrie, Conrad Technologies, Inc. *Frontal Offset Crash Study Using 50th Percentile Male and 5th Percentile Female Dummies.* Paper No. 98-S1-O-01, The 16th International Technical Conference on the Enhanced Safety of Vehicles (ESV), Windsor, Canada, June 1998.

Park, Brian T., Susan C. Partyka, Richard M. Morgan, James R. Hackney, John Lee, and Lori Summers, National Highway Traffic Safety Administration, and Johanna C. Lowrie and Nathaniel M. Beuse, ALCOSYS, Inc. *Comparison of Vehicle Structural Integrity and Occupant Injury Potential in Full-frontal and Offset-frontal Crash Tests*. Paper No. 2000-01-0879, 2000 SAE International Congress & Exposition, Detroit, MI, March 2000.