THE ENGINEERING INSTITUTE, INC.

September 29, 2005

The Honorable Stephen R. Kratzke
Associate Administrator for Rulemaking
National Highway Traffic Safety Administration
400 7th Street, S.W.
Washington, DC 20590

RE: Docket No. NHTSA-2005-22143

Dear Mr. Kratzke,

After carefully reading the new roof crush regulatory proposal, it is my opinion that this rule would have a deleterious affect on the public's safety and should be rejected.

As you know, the number of rollover deaths is at the level of 10,000 per year. This is a significant public health issue. The proposed new standard of 2.5X/192mm will prevent, by NHTSA's own estimates, only about 0.5% of the rollover fatalities. Further, it will provide economic incentives to automotive manufacturers such that no further lives be saved. I encourage the agency to pursue a standard that ensures that, upon enactment, vehicles of the future are produced in accordance with today's best practices, making vehicle roofs as strong as the Subaru Forester and Volvo XC90. These roofs have been shown to be highly effective as well as technically and economically viable.

While there are some items within the proposal with merit (e.g., extending the standard to vehicles with a GVWR of 10,000 lbs; recognition of a need for an increased strength requirement; correction of minor technical deficiencies), if one of the goals of this proposal is to indemnify manufacturers against claims of negligence, then the standard should be one that unquestionably protects future passengers using the best practices of today. The proposal does not do this.

My principal objection to the new standard is that it raises the strength requirements for the roofs of vehicles by less than 10%. While at first glance the change from a 1.5X roof strength requirement to a 2.5X roof strength requirement seems to be a dramatic improvement, it is not. This is because the amount of intrusion allowed is dramatically increased. According to the NPRM, the 2.5X force must be reached before the headform of a 50th percentile hybrid III dummy is contacted by the headliner as pressed by the platen. However, by reading the report by Rains and Voorhis [Ref 87 of NPRM], we find (page 18) that the average crush at occupant contact for the 9 vehicles tested was 194 mm (7.63"). The old standard, which by the very nature of the proposal is deemed inadequate, called for the resistance force to be achieved at no more than 127 mm (5.00") of platen travel. Thus, while the force standard has increased from 1.5X to 2.5X (a 67% increase), the amount of room allowed to reach this increased force is a 53% increase. This means that, by reasonably assuming a linear roof crush resistance response, at the previous

5” platen travel, a 2.5X/194mm roof would give a resistance of a mere 1.64X vehicle weight. This is a minor 9% increase in required roof strength. Please note that any manufacturer that maintains a non-zero but unexceptional factor of safety for their current production roof designs will find that their old roofs meet the new standard. This analysis is confirmed within the NPRM, which indicates that 7 of 10 tested vehicles pass the new standard. Thus, for approximately 70% of the domestic fleet, the new standard directly translates to *business as usual*, with the added benefit of immunity from lawsuits. It also does not stretch one’s imagination to envision roofs of the future with poor energy management that pass the newly proposed standard at 194mm but could not pass the old 127mm standard.

Additionally, the methodology used to select a quasi-static force of 2.5X based upon drop tests is fundamentally flawed. According to Newton’s third law, “for every action (force) in nature there is an equal and opposite reaction.” This means that one body cannot act on another body with a force greater than the impacted body’s ability to resist. In drop testing, the reaction force of the ground (with an associated transducer to measure force level) is governed not by the stiffness and strength of the ground, which is fixed, but rather by that of the vehicle’s roof as it deforms upon impact. The more it deforms, the less peak force is needed to absorb the kinetic energy of impact [Kinetic energy of impact (ignoring compressive effects) = vehicle mass * gravitational constant * drop height; Roof energy absorption = ½ * roof stiffness * deformation^2]. Notice from the previous equations that if the roof stiffness increases, the deformation decreases. However, since the energy term is quadratic in deformation, deformation decreases at the square root of any increase in roof stiffness. That is, by doubling a roof’s stiffness from, say, *A* to *2A*, the deformation decreases from, say, *B* to *0.707B*. Since resistive force follows a spring constant rule (stiffness*deformation), a doubling of roof stiffness indicates a 41% increase in impact force. Thus, by using research based upon existing 1.5X/127mm *weak* roofs, the agency systematically underestimates the amount of impact force that a *strong stiff* roof would endure. Rather than using roofs that are compliant with the old standard, the results of drop tests of Subaru Foresters and Volvo XC90s should be used. Further, the tests should not be based upon the curb weight of the vehicle, but should be based upon the weight of the vehicle plus belted occupants who will augment the force applied to the roof.

The usage of static headroom within the NPRM is also flawed. The proposed rule gives no mention of seatbelt performance, affecting the available dynamic headroom. The amount of dynamic headroom is the only measure of true value, as roof crush does not occur with the vehicle in its normal 4-wheels to the ground orientation. It is my recommendation that the NHTSA includes a methodology to incorporate the effects of seatbelt performance, rewarding those manufacturers (and therefore consumers) whose vehicles have pretensioners or other effective anti-excursion technologies. There are various obvious techniques that could be used to accomplish this, such as a spit test to determine excursion of a 95th percentile dummy within a -1g environment. The measured maximum point of the applicable portion of the headform would determine the headroom used for the newly modified FMVSS216 test. I do not support the use of a 50th percentile male dummy in a +1g environment for the determination of headroom, as it is scientifically invalid, and will yield a higher number of paralyzed and killed occupants.

The NPRM indicates that other technologies and strategies are being pursued. Such technologies could include electronic stability control, side-curtain airbags, and laminated occupant retention glazing. When coupled with a strong roof, these provide the maximum opportunity for occupant survival. Please see *Appendix A* for a narrative detailing the rollover performance of a Volvo XC90 with a strong roof, pretensioners and side curtain airbags. Although this vehicle was equipped with ESC, it was impacted and underwent a highway speed rollover in excess of 50 mph. The roof stayed up, the side curtain airbags deployed, and the pretensioners fired. The two belted front seat occupants walked away with non-serious injuries. In my opinion, this level of performance should be the goal of the new rule.

Prevention of rollovers should also be addressed; it is easiest to survive the rollover that never occurs. Regarding rollover countermeasures, it is my recommendation general passenger vehicles in the factory new condition should not roll over as a result of driver steering inputs alone. I disagree with the NCAP program referenced within the NPRM providing rollover risk predictions. This strategy will ensure that vehicles that are unsafe in emergency situations will continue to be marketed. Of course, these high center of gravity vehicles will continue to contain a helpful warning label on the visors that encourages the driver not to get into an emergency situation; and, if in one, not to react using instinctive behavior. This prominent label gives fair warning that if a child chases her ball out into the street in front of your SUV that you should train yourself to simply run her over, rather than take the risk of an emergency avoidance maneuver leading to a rollover due to your own "driver error."

Of course, it is known that even with ESC, some vehicles will roll over. Most of those will contain belted occupants. As was shown by Deutermann [Reference 22 of NPRM] a full 28% of occupants fatally injured in rollover collisions were belted. This indicates the problem severity of roof intrusion and partial ejection through side glazing, which are inter-related crashworthiness issues. Real accidents and rollover testing confirm that individual side glazing panels are significantly less likely to shatter in vehicles with strong roofs than with weak roofs. I encourage NHTSA to re-examine their decision to not require occupant retention glazing in vehicles. *Appendix B* gives information regarding a SUV that underwent a mere ¼ roll, skidding to a halt. Body deflection induced side glazing fracture. The belted front seat occupant saw life-altering injuries through partial ejection through the open window portal (loss of most fingers and both thumbs). These injuries were completely preventable. Vehicles are already being sold advertising their occupant retention glazing capability. *Appendix C* shows a 2005 Volvo S80 window made with laminated glass. The highlighted pictogram indicates that this glazing helps retain occupants in collisions.

Using the consumer price index (http://minneapolisfed.org/Research/data/us/calc/index.cfm), it was possible to compare the current roof crush proposal to the previously proposed occupant retention side glazing technology. According to NHTSA's analysis [Ejection Mitigation Using Advanced Glazing, A Status Report, 1995], "Estimated cost per equivalent fatality prevented is $563,463 and $931,827 [1995 dollars]." The inflation rate has been 28% according to the cited reference. This would mean that laminated side glazing would cost 721,232-1,192,738 of today's (2005) dollars per equivalent life saved (with trilaminate glass, the most likely candidate, being the least expensive). Since the NPRM for roof crush indicates that the cost per equivalent life saved is $2.1-3.4 million, it is obvious from an efficiency standpoint that laminated side glass should take precedence, especially since it is projected to save many more lives than the new roof strength rule as proposed.

Further, the door mounted window frames are significant to crashworthiness. These frames can cause the glazing within to fracture when they are bent, and also can act as portals of partial or full ejection. In my consulting work on crashworthiness, I have seen the unfortunate results of numerous side impact and rollover collisions in which the occupant's head or entire body goes between the door and the roof rail through deflection of the window frame. Frame strength in bending is not currently regulated, and accidents have shown that this can be a critical safety component.

With regard to the inclusion of the windshield during roof intrusion testing, it seems imprudent to use a brittle ceramic as a structural member. Even in XC90 rollovers, windshields crack. However, the desire to test the vehicle as produced is compelling, and if the strength requirement is sufficiently high, then the presence or absence of the windshield should not be significant. It is my belief that a 2.5X standard is not sufficient, and therefore the windshield should not be present for testing. If the standard is raised to 3.5X or 4.0X, then the inclusion of the windshields within the test is probably not objectionable.

It is significant to read (section V. B.), “In sum, the agency believes that there is a relationship between the amount of roof intrusion and the risk of injury to belted occupants in rollover events.” There are those who vehemently dispute this causal relationship. That said, I think a point of common understanding is that if the head doesn’t contact the roof during a rollover, then no head, neck or spinal injuries will occur, at least with respect to roof contact. I encourage the NHTSA to make the goal of this standard that in a highway speed rollover that no roof contact will occur in any passenger car for 95% of the driving population. It is my opinion that if the agency can conduct numerous (e.g., 12-20) FMVSS 208 rollover tests using vehicles that are compliant with the new standard, using production belts and 95^{th} percentile ATDs showing no head to roof contact bringing about objectionable loading, that the proposal to pre-empt product liability legislation is, to the layman, warranted. However, if a half measure is implemented that makes only 30% of the vehicles only trivially stronger, saving only 0.5% of those killed in rollovers, then the proposal to indemnify vehicle manufacturers is in my opinion unjustified, as the new standard would be inaccurately indicating that these vehicles are safe with regards to roof intrusion in rollover collisions.

Sincerely,

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Appendix A
Docket No. NHTSA-2005-22143 Comments by Dr. Stephen A. Batzer

According to the police report, the Volvo was driving on a California highway at a speed of about 65 mph. The vehicle was struck at the right rear quarter panel by another vehicle. The Volvo rotated clockwise, and rolled, driver's side leading. There were two occupants in the vehicle, a 45 year old female driver and her 9 year old son in the #3 seating position. Both were seatbelted. Both occupants complained of neck and back pain, as well as minor scratches to their arms and hands. Both walked away from the accident. The vehicle, VIN YV1CM59H531012001, in the salvage yard is depicted below. Notice that after a highway speed rollover that only crease denting of the roof is shown. The windshield cracked but did not dislodge from the periphery during the accident. Only the front two tempered moveable windows broke.

2003 Volvo XC90, 2.5 liter turbocharged engine, 5 speed automatic transmission, in salvage yard.

Appendix B
Docket No. NHTSA-2005-22143 Comments by Dr. Stephen A. Batzer

According to the police report, the vehicle depicted below was traveling in rural Tennessee. The driver drifted onto the right shoulder of the roadway. To recover from the road edge, she steered left, and then steered right again, going back into the ditch. She then turned left again. The vehicle overturned, passenger side leading, and came to rest in the roadway. During the rollover, the glazing in the passenger front vehicle shattered, and the belted 6-year old boy was partially ejected, suffering life-altering injuries to both of his arms and hands.

1999 Ford Explorer 4-door. Passenger front glazing is broken, allowing partial ejection of occupant.
Notice blood underneath window in upper photograph.

Appendix C
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2004 Volvo S80 side glazing – monogram indicates occupant protection capability (left) and added security against “smash and grab” robberies (right).