Integrating OEM Vehicle ROPS to Improve Rollover Injury Probability

Susie Bozzini*, Nick DiNapoli** and Donald Friedman***

*Safety Engineering International Goleta, CA, USA
** Consultant
*** Center for Injury Research Santa Barbara, CA, USA

Abstract - Geometry is a subset of styling and almost all cars have the same generic roof geometry. Studies have shown, however, that geometry plays a big role in the depths of roof crush for a given rollover impact scenario. However, consumers are misled by a rollover propensity rating on safety charts with dynamic frontal, front offset, side and rear crashworthiness ratings. Rollover crashworthiness has and continues to have the lowest priority in sales potential with consumers although 3% of accidents result in 30% of fatalities. Off-road fleet customers of work vehicles with high rollover fatality rates see the situation differently and equip their vehicles with aftermarket rollover occupant protection systems (ROPS). This paper compares the styling and rollover performance of the original designs, the same vehicles with a patented external ROPS (HALO^{TM}) and as modified with an OEM version of the same patent.

Keywords: OEM, ROPS, HALO^{TM}, rollover, injury criteria

INTRODUCTION

In the automotive world marketing/sales is King and styling is Queen. Geometry is a subset of styling and almost all cars have the same generic roof geometry. Studies have shown that geometry plays a big role in the depths of roof crush for a given rollover impact scenario. Consumers are misled by a rollover propensity rating on safety charts with frontal, front offset, side and rear crashworthiness ratings. Compared to styling the fuel economy sales issue has been mitigated by hybrid electric and lightweight high-strength steel structure glued in place. Rollover crashworthiness has and continues to have the lowest priority in sales potential with consumers. Fleet customers with hundreds or even thousands of company owned work vehicles, with high rollover fatality rates, see the situation differently and equip their vehicles with aftermarket rollover occupant protection systems (ROPS). This is an additional cost that those responsible companies choose to bear, rather than see any of their people catastrophically injured in a company owned vehicle. One of these companies has made the argument that the responsibility remains with the vehicle OEM's and that they should provide cost effective production vehicles that perform as well as vehicles with aftermarket ROPS.

OBJECTIVE

The objective of this paper is to suggest that there are solutions for the OEM's to use to enable their production vehicles to perform well in the rollover crash mode without aftermarket ROPS. The Author's undertook a redesign and restyle of two of the most popular Dual Cab work vehicles of the Oil, Gas and Mining industries: the Mitsubishi Triton and the Toyota Hilux to show how a potential integrated ROPS would satisfy the OGM need for a rollover capable vehicle.

METHOD

An analysis of the patented aftermarket HALO^{TM} ROPS [1], shown in Figure 1, enabled the Author's to suggest what roof areas would need reinforcement to enhance performance. Sketches of the new design required to achieve this performance level were then drawn. Additional drawings were made of the vehicle modifications to the original, the aftermarket HALO^{TM} version, and the integrated OEM HALO^{TM} versions. An analysis of the expected decrease in injury risk for occupants was calculated using the Injury Risk probability chart from Sam Mandell [2].

Figure 1. Patented aftermarket HALO™ ROPS fitted to a Toyota Hilux Dual Cab Truck

DISCUSSION

The last time vehicles were built with significantly rounded roof geometry was in 1979 with the Minicars Research Safety Vehicle (RSV) shown in Figure 2. This vehicle was designed under contract to the then National Highway Safety Board (NHSB), now the National Highway Traffic Safety Administration (NHTSA) and was intended to show that vehicles could be built safely to withstand the forces in the various crash modes encountered on modern highways.

Figure 2. RSV ¾ Frontal view

Now 35 years later Nick DiNapoli the original RSV designer/stylist has updated the RSV design, shown in Figure 3. In particular he re-designed the structure, the geometry and the styling to reflect the patented HALO™ ROPS [2] OEM rollover design features. The required modification decreases the radius of the B-pillar such that it is about 4” higher at the center, rounding the load bearing surface of the roof at the center of gravity (CG) and rearward, creating better rollover performance. The geometry change is almost imperceptible on the styling.

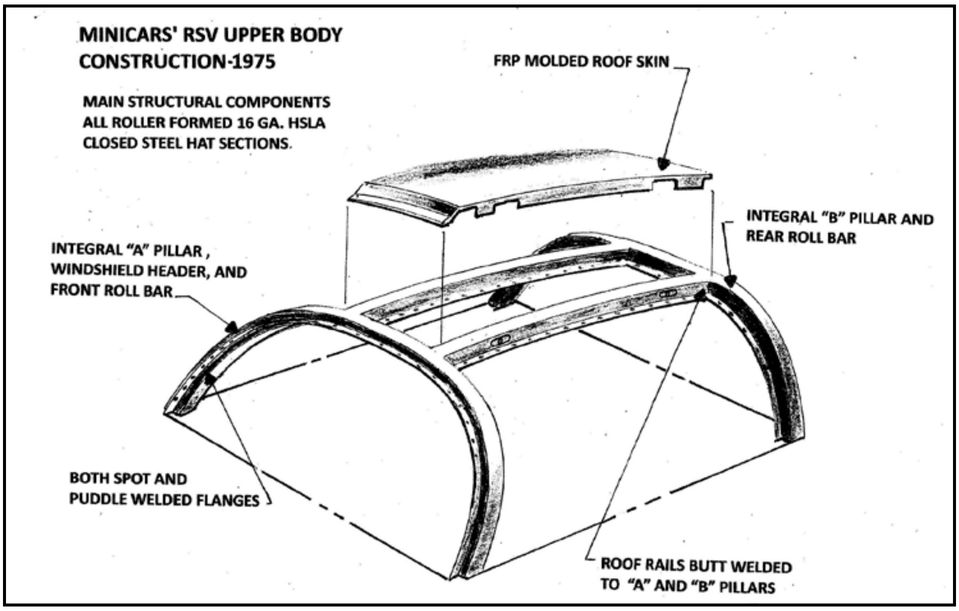

Figure 3. RSV redesign sketch to round roof and enhance pillar support.

RESULTS

Comparative concept evaluation

Two concepts were developed for an OEM ROPS on the current Mitsubishi Triton Dual Cab Truck and the Toyota Hilux Dual Cab Truck.

Concept "A" which reduces the Major Radius (MR- the vertical distance between the intersection of the roof rail header and A-pillar to the longitudinal center of gravity), would modify the body structure, doors, window frames and header reducing the overall height of the aftermarket HALO™ vehicle by about 4" and its Major Radius by about 3" as shown on the Mitsubishi Triton Dual Cab Truck in Figure 4.

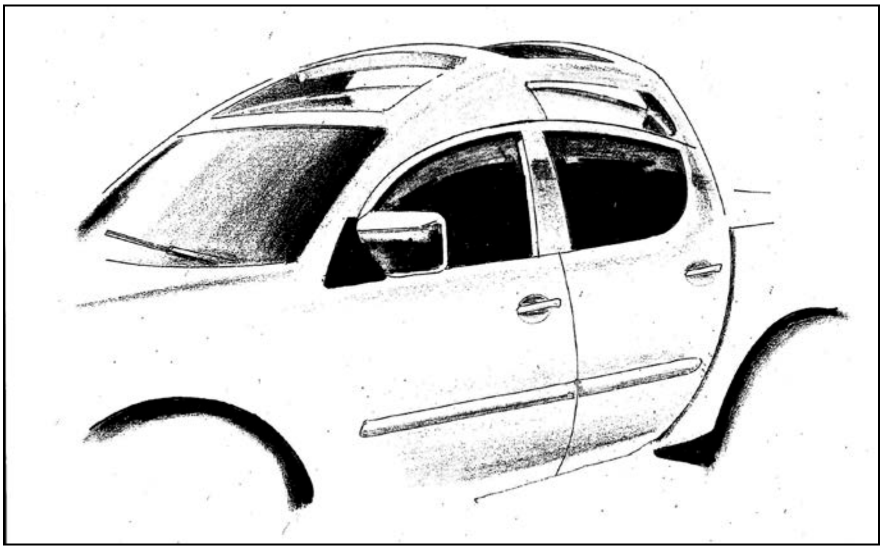

Figure 4. Concept "A" - Integrated OEM production modification for improved rollover protection.

These changes have little effect on the styling, but require the manufacturer to change the A- and B-pillars, the door frame and seals, in addition to the roof panel. The effect would be a reduction of the aftermarket HALO™ residual crush by about 40%. This would enhance rollover performance, however, the drawbacks include ease of entry and exit being reduced and the re-tooling costs to the OEM may be substantial.

Concept "B" substitutes an integrated sheet metal roof structure with the geometry of the aftermarket HALO™ which would be attached (glued) to the existing roof rails. Figure 5 shows the components of this approach.

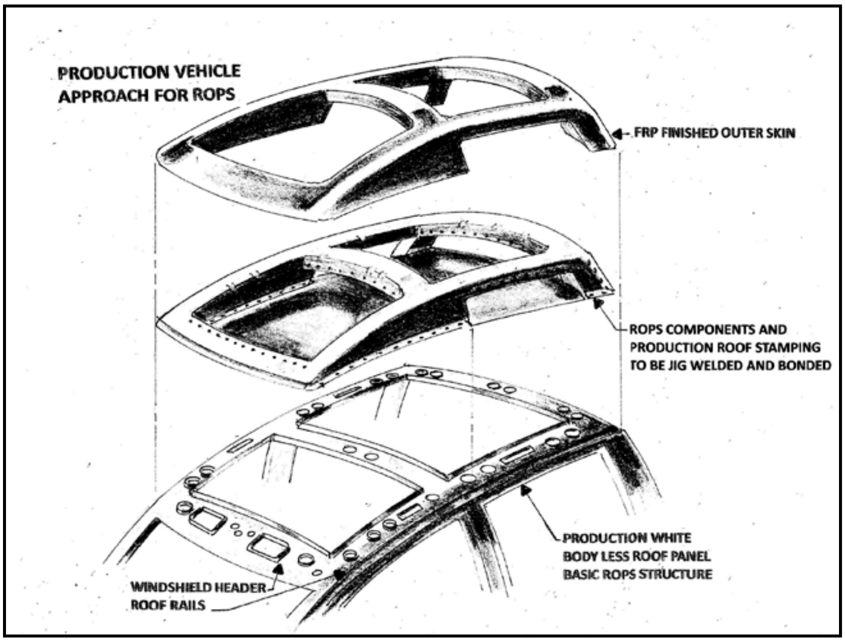

Figure 5. Concept "B" Production vehicle approach for integrated ROPS

Figure 6 shows the components of this approach and illustrates their assembly.

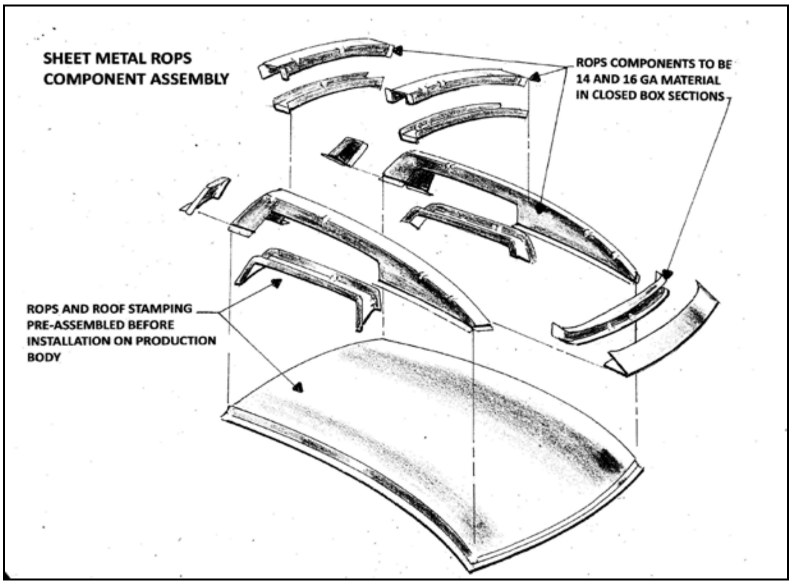

Figure 6. Concept "B" Sheet metal ROPS component assembly

Comparative production design and styling

The styling of the sheet metal integrated structure of the Mitsubishi Triton is compared to the original and the aftermarket HALO™ version in Figures 7 to 9.

Figure 7. Original 2012 Mitsubishi Triton Dual Cab

Figure 8. HALO™ ROPS Equipped Mitsubishi Triton Dual Cab

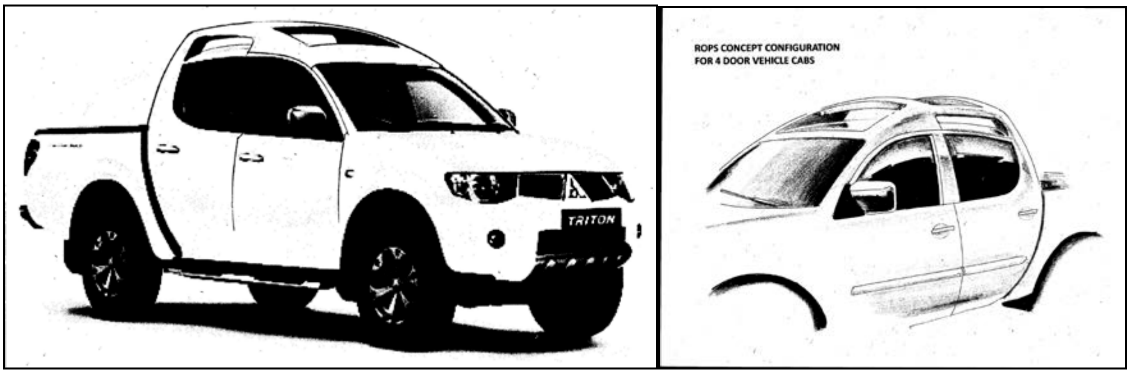

Figure 9. Concept “B” OEM version of Mitsubishi Triton Dual Cab

The Concept “B” styling of the sheet metal integrated structure of the Toyota Hilux is compared to the original and the aftermarket HALO™ version in Figures 10 to 12.

Figure 10. Original Toyota Hilux Dual Cab

Figure 11. After market HALO™ version of Toyota Hilux Dual Cab

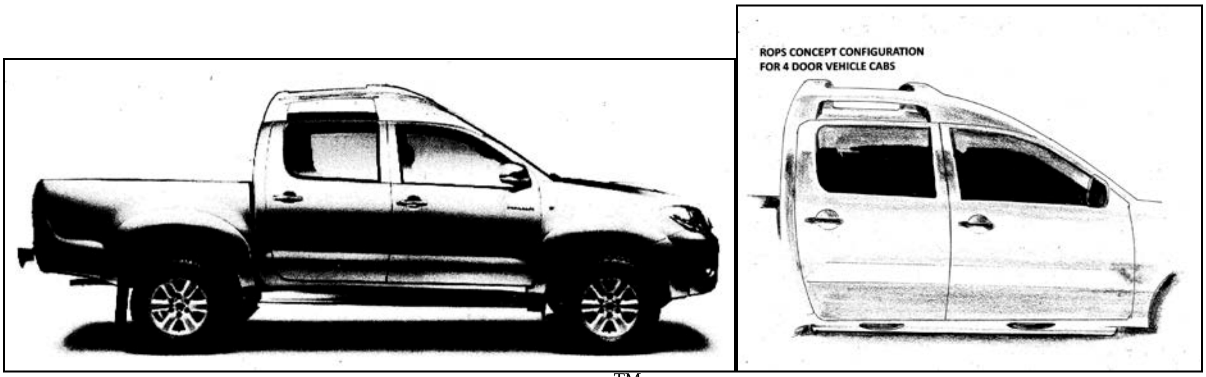

Figure 12. Concept "B" OEM HALO™ version of Toyota Hilux Dual Cab

Comparative performance

The probability of injury at the level of AIS 3+ has been statistically derived as a function of compartment residual crush from the U.S. National Accident Sampling System (NASS-GES) and CIREN data files as shown in Figure 13.

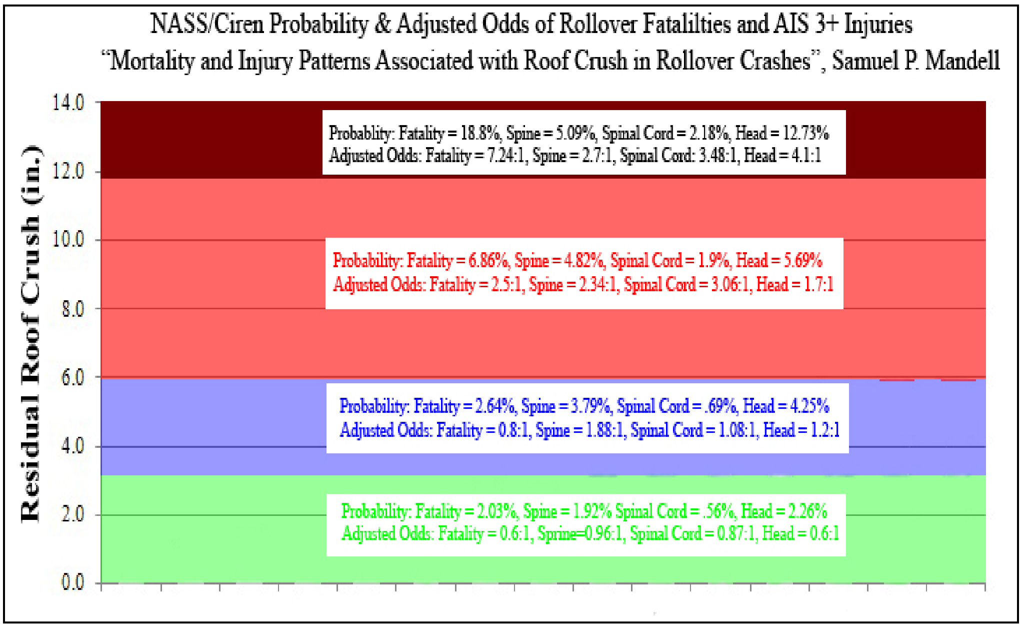

Figure 13. The probability of injury as a function of residual crush in the front compartment

The performance of the aftermarket version on SUV vehicles was determined by JRS and Dolly rollover tests of a weak roof (SWR = 1.7) structured 1993 Jeep Grand Cherokee and one equipped with a prototype HALO™.[3] The vertical residual crush of the production vehicle at a real world test protocol was 9 inches. The same vehicle with a prototype HALO™ was tested in a sequence of 3 JRS rollovers at 18 mph with a cumulative total of 4 inches of vertical intrusion at the A- and B- pillar. The dolly rollover at 42 mph with 3 rolls had a similar cumulative crush at the A- and B- pillars of about 4 inches.

Figure 14 describes the relationship between residual crush and the Major Radius (the vertical distance between the intersection of the roof rail header and A-pillar to the longitudinal center of gravity).

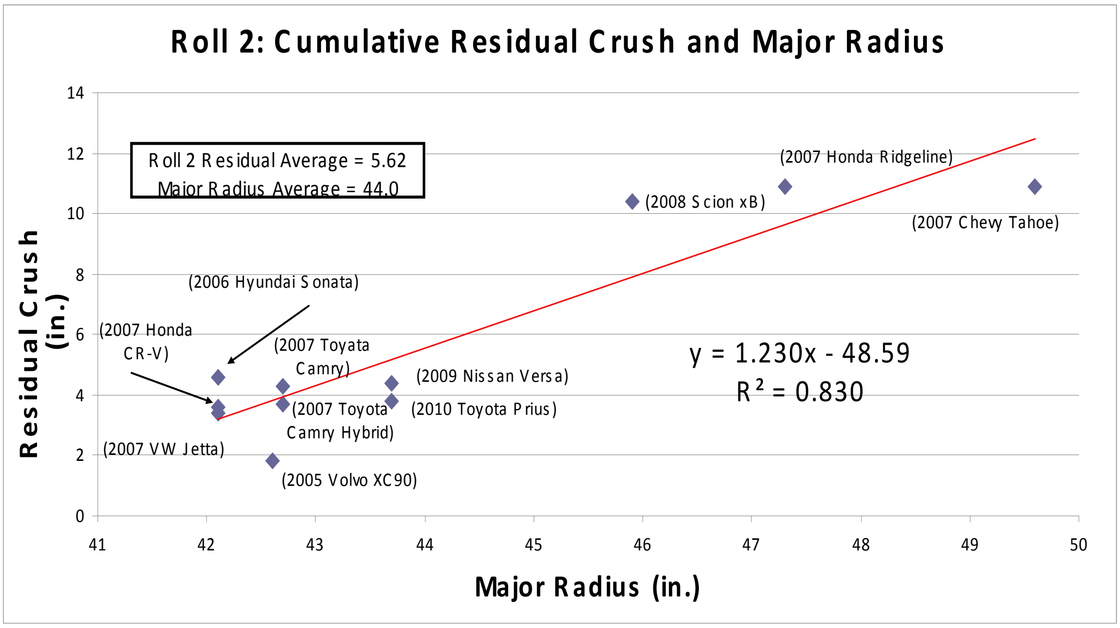

Figure 14. Cumulative Residual Crush vs Major Radius

Injury probability as a function of major radius

A study of the measurement of Major Radius across several vehicle types was conducted. This showed that the Major Radius of most Dual Cab truck type vehicles is in the range of 47 inches. Vehicles with a radius at this size in testing resulted in about 9 inches of vertical residual crush. A reduction of 3 inches of Major Radius to 44 inches reduces residual crush from about 9 inches to 5 inches or less. The aftermarket HALO™ does not change the Major Radius to reduce residual crush. Rather it limits the impact forces on the front, weak sections, of the vehicle roof. Maintaining the aftermarket HALO™ geometry in the Concept "A" design (reduced Major Radius) could reduce the residual crush further to 3.5 inches.

Figure 15 shows the comparative vertical residual crush of the Jeep Grand Cherokee and Dual Cab equivalence with and without aftermarket HALO™ overlaid on the injury probability charts.

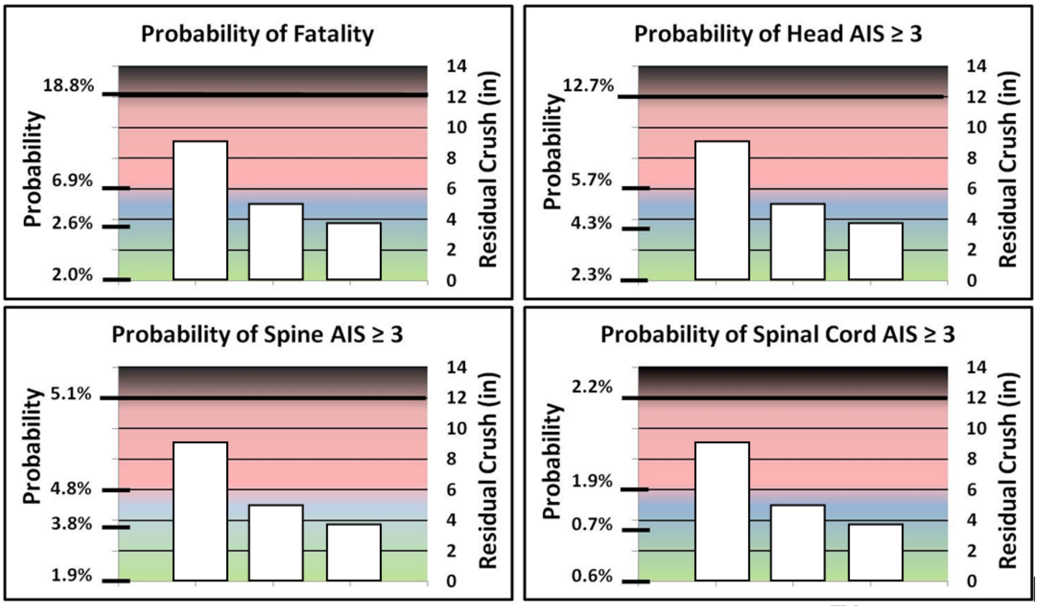

Figure 15. Production Vehicle, Vehicle equipped with aftermarket HALO™ and Concept "A" (reduced MR) injury probability bars, respectively.

The three bars represent the production, HALO™ equipped and Concept "A" designs, in that order. Since the sheet metal OEM geometry and strength would be the same as the aftermarket HALO™ version, it would have similar performance. The third bar represents the performance of the Concept "A" design (with reduced major radius). As shown, the residual crush with Concept "A" is about 40% less than the aftermarket and sheet metal versions but the probability of a fatality is not significantly reduced as compared to the potential OEM tooling costs.

CONCLUSION

The HALO™ ROPS patent, applied either as an aftermarket or OEM design, reduces the Dual Cab Truck probability of a fatality from 14% to 4%.

In considering Concepts “A” and “B” for an OEM version of the aftermarket HALO^{TM}, Concept “A” (reduced MR) reduces the probability of a fatality from 4% to 2.6% at a substantial tooling cost which makes it unlikely any manufacturer would invest in that design concept.

The sheet metal version Concept “B” which performs as well as the aftermarket HALO^{TM} requires a minor tooling investment and significantly improves the styling without changing the basic Dual Cab structure. The competitive sales advantage to a manufacturer and the reduced cost to the fleet consumer may make the OEM version a worthwhile investment.

REFERENCES

1. USPTO HALOTM ROPS Patent #7717492 Safety Engineering International 2008.

2. S Mandell, R Kaufman, C D Mack, E M Bulger, ‘Mortality and injury patterns associated with roof crush in rollover crashes’, Accident Analysis and Prevention, 2010, doi:10.1016/j.aap.2010.02.013.

3. R H Grzebieta, D Friedman, ‘Vehicle roof geometry and its effect on rollover roof performance’, 21st International Technical Conference on the Enhanced Safety of Vehicles (ESV), Paper Number 07-0361, Stuttgart, Germany, 2009.