Research Safety Vehicle Tests Show Promise

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Two research safety vehicle (RSV) programs have been sponsored by the National Highway Traffic Safety Administration, U.S. Department of Transportation, as part of the government's efforts toward safer transportation.

One, conducted by Calspan Corporation, with Chrysler as the major subcontractor, adapted a 1976 model year production car to provide enhanced safety and fuel economy. The Calspan-Chrysler approach resulted in the redesign of crashworthiness structure by using conventional automotive sheet-metal construction but employing high-strength, low-alloy (HSLA) steel in critical areas to reduce weight. A polyurethane front bumper and facia were incorporated that under test conditions indicated a halving of struck pedestrian loads and provided damage-free protection to the car in 8-mph barrier crashes. This soft front-end design was also tested to reduce crash loadings on occupants of other vehicles that were struck in the side by the RSV. The Calspan-Chrysler RSV design incorporates many other safety advances and provides good fuel economy with controlled emissions. Technical reports and papers presented during this program have guided the automotive industry in achieving improved safety and fuel economy by using accelerated evolutionary design that does not tax current production know-how in the automotive industry.

The other RSV program was conducted by Minicars, Inc., of Goleta, California. It started with a completely new design. The objectives were to demonstrate new techniques of car design and construction that could be practical and economical for mass production while providing dramatic safety improvements at affordable prices, with increased fuel economy and improved emissions. The need for substantial crashworthiness improvements in small cars has become more apparent because of the increasing number of newer light cars mixed in with the older and heavier cars on the nation's highways.

When two cars collide, the force acting on each is the same, but the acceleration imparted to each is inversely proportional to its weight. Therefore, when a light and heavy car crash together, the light car will experience higher crash accelerations than the heavier car. These higher accelerations normally result in greater injury to the occupants. Crashworthiness levels of light cars must be substantially increased if dramatic increases in deaths and severe injuries are to be avoided as greater numbers of crashes occur between light and heavy cars due to the growing small-car population.

Maximum use of stock subsystem elements is made by Minicars in the RSV to keep development costs as low as possible. In some cases, this practice has led to RSV performance that is not ideal but could have been substantially improved by investment of additional effort in development of subsystem elements. An example is

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seen in the four-wheel disk brakes used in the RSV. These are stock Fiat production items, part of the McPherson and Chapman strut assemblies found on the Fiat X1/9. Investment in developing larger rotors would result in shorter stopping distances than the RSV now achieves, but current actual RSV stopping capabilities satisfy federal motor vehicle safety standards. Because shorter stopping distance design is clearly within the existing state of the art and is well known to all manufacturers, a development expenditure to achieve such improvement would not yield as much benefit as those same dollars spent in demonstrating new technology. The balance between development investment in old technology and that for new technology is extremely sensitive. The Minicars RSV is intended to demonstrate the benefits of new technologies and the vehicle should also possess all of the desirable automobile characteristics provided by direct application of existing engineering practice. The final RSVs contain components from several production cars, most of which would benefit by reduced weight, or improved performance, or both if they were initially engineered for the RSV application. These compromises were made to allow sufficient funding for significant advances in state of the art in selected subsystems of highest-benefit potentials.

Subsystems affecting car crashworthiness, those protecting the occupants in a crash, were emphasized in development. Ideal would be a passenger compartment that prevents crash intrusion and structures surrounding it that would crush at loads producing compartment accelerations consistent with occupant protection. With this in mind, an innovative lightweight rigid foam-filled structure was developed for the RSV.

The RSV structure uses thin (0.030 in) standard automotive low-carbon cold-roll steel bent and welded into large hollow closed sections. These closed sections are then injected with the liquid reagents that produce a rigid 2-lb/ft^3 polyurethane foam to completely fill the hollow sections. Because the metal in these closed sections is remote from the structural centroid, the resulting structure is much more rigid in elastic bending and torsion and offers higher elastic column stability than an equal weight steel section of smaller exterior dimensions such as is most commonly found in current car structures. Furthermore, during a violent crash the foam-filled structure tends to collapse in an accordion fashion, offering a near constant force resistance as the crush continues.

As used in the RSV for front and rear primary structure, the foam-filled frame provides maximum crash energy absorption—consistent with both available crash length and the force limit creating accelerations tolerable to the occupant protection systems. The foam-filled structure is also used for the passenger compartment and doors where it provides lightweight high-intrusion resistance due to its high elastic rigidity.

The front-seat occupants are restrained in frontal crashes by air bags stored nonintrusively in the steering wheel hub and dashboard. Both air bags have a quick deployment (25 to 30 ms) upper-torso restraint and a slower deploying and softer compartment for head restraint. The air bag system for the driver is provided with a forward stroking capability during crash at a controlled safe maximum force level by the special steering column design that reacts to the air bag loads. Crushable knee bolsters control lower-torso deceleration for both the driver and front-seat passenger. Crash tests have shown that the

Calspan research safety vehicle.

front occupants of the RSV are protected in 50-mph crashes against rigid concrete barriers. Safety standards demand 30-mph occupant protection in current production cars and then only when all provided restraints are used by the occupants. Because crash energy is a function of the square of velocity, the RSV, therefore, safely absorbs 2.77 times the energy required by federal standards and protects its occupants without their having to take any actions to apply restraints prior to the crash.

The front occupant on the impacted side of a moving RSV was protected in side crash against the RSV passenger compartment by a large car with a closing speed of 50 mph. The rigid RSV side structure and doors, in conjunction with the crushable side padding, provided this exceptional occupant protection. The RSV has been subjected to many other crash conditions, including offset and aligned car-to-car frontal tests; aligned, angular, and offset barrier tests; rollover and rear-end crash tests; and moving tow-car side crashes. Its instrumented anthropometric dummies, simulating human occupants, indicated that RSV passengers are provided levels of crash protection far in excess of those provided by any known production car.

The RSV fenders and exterior front and rear ends make extensive use of reaction injection molded (RIM) polyurethane to save weight and to reduce damage to these commonly struck surfaces; RIM has approximately 1/8 the density of steel. Resilient plastic foam is used for bumpers. A 16-in long foam-filled structure is directly behind the resilient front bumper to elastically react to bumper impact loads. Its front edge is at the height of conventional car side sills. It is designed to crush at loads below those required to crush the primary RSV crash energy management structure to which its aft surface is bolted. The resulting front end of the RSV accomplishes the following:

1. Provides damage-free frontal crash protection in rigid barrier crashes of from 8 to 10 mph;
2. Dramatically reduces pedestrian impact loading at speeds up to 25 mph;
3. In frontal barrier crashes above 10 mph and below 20 mph, confines all significant structural damage to the replaceable bolt-on front end that can be economically replaced, frequently with little or no repair required on the RIM elements; and
4. As demonstrated in test, appreciably reduces intrusion and crash loadings on occupants of conventional production cars when struck in the side by an RSV (the RSV soft foam bumper, its side-sill height front end, and its lower crush-strength sacrificial bolt-on front structure all contribute to the protection of other car occupants).

The Minicars RSV uses vertically opening gull-wing-type doors. This feature is not essential to the crashworthiness of the RSV but has been retained since RSV inception, despite some controversy, because a vertically opening door was more compatible with a passive-belt occupant-restraint system than a more conventional laterally opening door. Air bags have always been intended for RSV front-seat restraints; however, it was decided to maintain the potential for future development of improved automatic belt systems. Another unique door design feature is the use of laminated side glazing permanently fixed in place on the doors. Ventilation and outside access are provided through a narrow fore-aft slide

Minicars research safety vehicle.

Minicars large research safety vehicle.

window at the base of the large area side glazing. The fixed-in-place laminated glass was used to avoid the deficiency of conventional tempered glass that, even if the window is closed prior to a side crash, will frequently shatter and allow ejection of the occupant or portions of the occupant's body. The fixed-in-place laminated glazing prevents lateral ejection of the RSV occupant into the striking range of the hood or fenders of the impacting car. Because one of the major functions of lap belts in cars equipped with air bags is to prevent lateral ejection in side-crash and rollover accidents, lap belts are not essential in the RSV. The RSV front-seat occupants are therefore provided with fully passive and effective protection, requiring no prior action on the part of the riders to receive maximum protection in the event of a crash.

Additional state-of-the-art advances are demonstrated in an RSV referred to in the program as the high-technology RSV. This vehicle is equipped with a five-speed automatic transmission developed by Minicars and Dubner Computer Systems. This eliminates fluid coupling losses of conventional automatics and offers the fuel economy benefits of a manual five-speed transmission. It incorporates a cruise control that offers conventional set-speed control, but additionally provides a button that will automatically accelerate the car through its gear shifts to 55 mph and then maintain that speed. Under cruise control, it will automatically reduce throttle on the RSV in an attempt to maintain a safe headway clearance should the traveling lane become blocked by a slower moving vehicle. The same radar system developed by RCA, which detects vehicles ahead to slow the RSV, will also apply severe braking to reduce crash speed should an accident no longer be avoidable. The automatic radar-activated braking will not override driver decision in braking action to avoid a crash unless the driver has done nothing. If the driver is already applying brakes or changing direction, automatic severe brake application will not occur. In testing, the automatic radar-activated brakes have been demonstrated against stationary targets. The RSV was automatically brought to a full stop with no action by the driver before target contact from an initial speed of 38.9 mph. In 46.1- and 50.5-mph tests, the RSV brakes were automatically applied by radar, reducing the RSV kinetic energy by 50 percent or more before target impact. The reduction of crash severity, which was the design function of the radar-braking system, has been well achieved.

The high-technology RSV also provides adaptive braking to the four-wheel disk brakes to avoid loss of control from wheel lockup. A driver information display mounted on top of the dash replaces conventional dials and meters with a digital and analog system that, in addition to normal car status information, will provide emergency messages should a hazard be detected by any of the sensors with which the RSV is equipped. All of these features are the result of current technology applications. The systems employed require further development, then miniaturization and production engineering, but their functional feasibility has now been demonstrated.

The utility and versatility of the technology developed in the four-passenger RSV were demonstrated in its applications to a downsized, popular four-door, six-passenger sedan made in Detroit. The six-passenger car modified by Minicars is referred to as the large research safety vehicle