

Edited by **Darlene Fritz**

## Vehicles get super mileage

Although none of this year's teams came close to breaking the 3145-mpg milestone set by the 2006 **University of British Columbia** vehicle, fuel stinginess still reigned supreme at the 28th annual **SAE Supermileage** event. For two days in June, competitors demonstrated strategies at **Eaton's** Marshall, MI, proving grounds for stretching the most mileage from their one-of-a-kind, single-occupant vehicles.

a previous SAE Supermileage entry and a first-year entry. "We base-lined things from last year to see where there was room for improvement, so it was like an R&D undertaking," said John Nassif, team leader for the first-year car. An extra 3 in (76 mm) of ground clearance, a 6-in (152-mm) shorter overall length, a carbon-fiber chassis, and fuel injection underscored the unique features of the team's newest car.

The team mounted both cars' engines between the driver and rear wheel, and both cars had the same centrifugal clutch chain drive to the rear wheel. "The old car was almost completely rebuilt from last year," said Jon Letourneau, team leader for the re-vamped car, which sported an aluminum-tube frame with a foam and fiberglass shell. While the team's old car took third place, their first-year car didn't finish. "The new car had loads of potential, but the crankshaft extensions on both of our engines broke," Nassif said, referencing the first-year entry.

The **Ivy Tech Community College of Indiana** team drastically altered their 2006 vehicle. "If you took the body off, it's a brand new car," said team leader Ryan Ross, who estimated that 90% of the car's parts were custom-made. "When you have an original design, your parts have to fit within that design. In reality, almost everything had to be slightly tweaked. For instance, the throttle handle is made for a lawnmower, but we had to bend it down and shorten it so that it would fit within the car," Ross explained.

Team leader Yashpal Singh Yadav and other members of India's **Delhi College of Engineering** were confident that their third Supermileage year would be the charm. They expected a substantial mpg benefit from a customized electronic fuel injection (EFI) system. "The fuel injector is from a **Honda** moped sold in Thailand. We got a programmable ECU from **Ucal**, an automotive supplier. And the rest of the parts, including the fuel pump and the ignition system, were downscaled from larger parts. If you had a normal-



KAMI BUCHHOLZ

Adham Abdulrahman puts stickers on the Bahrain Training Institute car, which finished with 198 mpg. The 2007 SAE Supermileage event marked the first year that a team competed from BTI, the largest vocational training institute in the Middle East.

Rules mandated that each vehicle have at least three wheels and use the same base engine—a donated **Briggs & Stratton** four-cycle producing 3.5 hp (2.6 kW) at 3600 rpm.

Teams could modify the engine and employ other technology tactics as a way to snare high mileage during a six-lap run on the 1.6-mi (2.6-km) oval test track. Regulations also required that a minimum of 9.6 mi (15.5 km) be completed in less than 39 min. That was a short time frame in comparison to the many weeks of prep time each team spent in the lead-up to this fuel-economy marathon.

The **University of Massachusetts-Amherst** team worked on two vehicles—

### Top Supermileage Finishers, the 1000-mpg Club

Collegiate Division	
1) Rose-Hulman Institute of Technology	1541 mpg
2) Cedarville University	1240 mpg
3) University of Massachusetts-Amherst	1125 mpg
4) Laval Universite	1119 mpg
High School Division	
1) Mater Dei High School	1693 mpg



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Chuck Ruggeri with the University of Akron team adjusts the 250-mL (8.5-oz) fuel bottle. All teams are required to use ISO-octane.

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Inner workings of the first-year entry car from the University of Massachusetts-Amherst are on display during technical inspections. In all, 20 schools passed technical inspections.

KAMI BUCHHOLZ



Members of New York's Binghamton University get ready to cruise at Supermileage.

RAMONA ELWELL

sized engine—meaning 1500 to 2000 cm<sup>3</sup>—you wouldn't have to customize the EFI system," said teammate Aniket Samat.

But the team's mpg-inspired work—including changes to gain ground clearance—went unproven in competition. "Delhi College never got their vehicle released from **U.S. Customs** in Chicago. The good news is that the competition has opened up some potential collaboration between the school and industry in India. This should be a mutual benefit to all parties," said 2007 Supermileage event organizer Jim Gluys, Principal Engineer for Heavy Transmissions at Eaton's Truck Components Operations.

As first-year Supermileage competitors, Ohio's **University of Dayton** team opted for an uncomplicated approach. "There's only three of us on the team, so we wanted to keep everything simple. We didn't want to start a project—like overhauling the engine—and not be able to finish the modifications we started," said Matt Boehle, team leader. That mindset is why the team left the engine alone, except for adding an electric starter, and primarily focused on vehicle aerodynamics—looking at eight body-shape iterations in 3-D modeling before wind-tunnel testing two scale models. "We wanted to know which of two different tail-end designs would be the best," said team member Adam Wangler.

Canada's **Universite' du Quebec ETS** built a new transmission for the 2007 competition. "The old transmission system was very lightweight. But with the loss of energy between the gear steps, it wasn't as efficient as we wanted," said

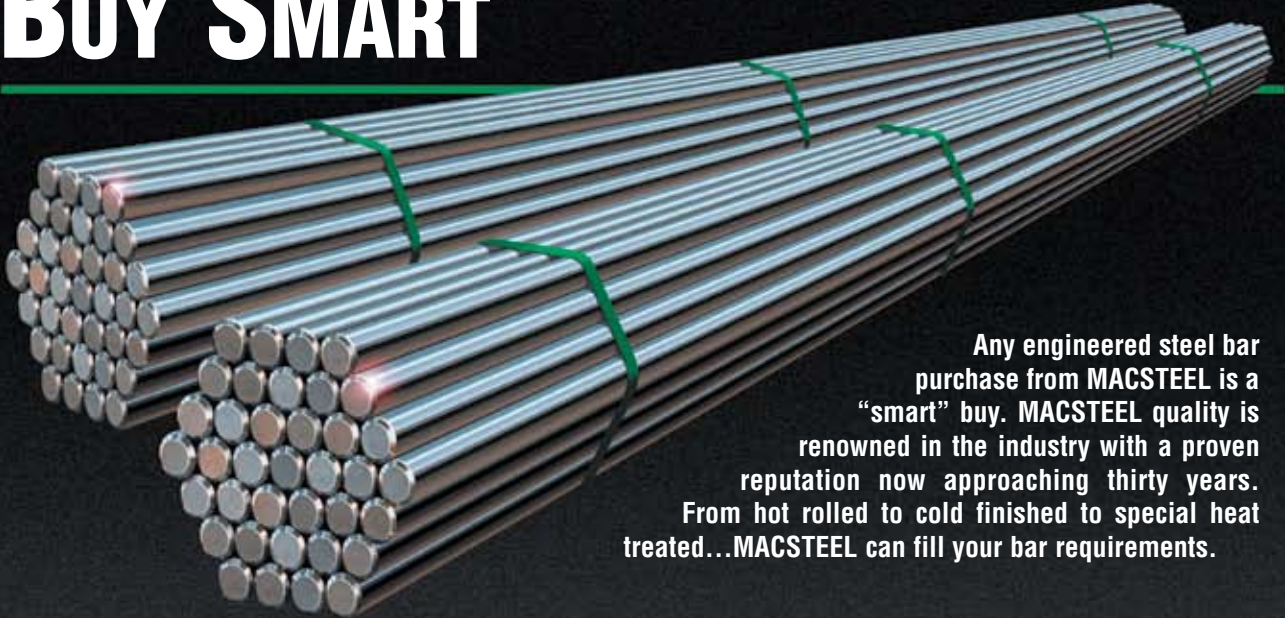
team member Simon-Pierre Harvey, adding, "The new transmission only uses one step of gears and has adjustable ratios. Plus, we made it compatible with a high-quality clutch. The end result—which was a lot of work to go from idea to final product in one month—is a more reliable, more efficient, and more versatile transmission system."

Indiana's **Mater Dei High School** retained its high-school division Supermileage champs crown. The team's 1693-mpg Supermileage tally surpassed their 1596-mpg third-place finish at the inaugural 2007 **Shell Eco-marathon Americas** event at the California Speedway in April. A key aspect of Supermileage lap strategy meant keeping a cell phone and a walkie-talkie engaged. "I communicate with my crew and that's how I know what to change and what to keep the same so as not to waste fuel," driver Danielle Ritter said.

For collegiate winner **Rose-Hulman Institute of Technology**, IN, repeatability and reliability made a difference. "For one thing, when we changed a variable, we knew what affect that would have on the car and that wasn't the case last year. This year, we were able to take a look at what we did on each lap and from that make adjustments to our driving strategy and engine tuning," said team captain Elliot Goodman, adding, "We were also changing fuel maps and clutch-engagement points after each six-lap competition run to try and tweak a little more out of the car."

Kami Buchholz

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## Quickness defines this process

The **Federal Bureau of Investigation** (FBI) employs rapid prototyping techniques as part of its crime-busting arsenal because it's an efficient and quick way to fabricate complex parts for the job at hand. But the U.S. federal investigative and intelligence agency isn't the only backer of fast parts production.

Users of rapid technologies include the automotive, aerospace, and architectural industries as well as the military, jewelry-makers, and the medical and dental communities. The bottom line: rapid technologies are rapidly collecting rave reviews.

"This is cool stuff. Imagination unleashed can result in major breakthroughs," Kevin Ayers, Mechanical Engineer in the FBI's Rapid Prototyping Facility in Quantico, VA, said after giving a quick glimpse of the agency's work with rapid metal parts production at RAPID 2007, a three-day Detroit conference in May sponsored by the **Society of**



A Brembo brake assembly was produced as a one-piece, composite-plaster part using Z Corporation's Spectrum Z510 3-D printer.



This sample geometry, based on a turbocharger-type application, demonstrates the capability of DMLS. The tiny, scaled-down part from Morris Technologies is made of cobalt chromium.

### Manufacturing Engineers.

The forte of rapid prototyping is fast parts making, yet each of the many processing methods available today—such as direct metal, selective laser sintering, fused-deposition modeling, and three-dimensional printing—offers a different set of advantages and disadvantages. "All of these processes have their specific attributes," said Carl Dekker, President of **Met-L-Flo**, an Illinois-based rapid-prototyping service center.

In a broad stroke, "rapid technologies" is a catch phrase for describing an additive fabrication process for building physical models, prototypes, or end-use parts directly from three-dimensional CAD data. Parts are built from plastic, liquid, powdered, or sheet materials by joining thin two-dimensional cross sections layer-by-layer based on the computer model, according to Sheku Kamara, Manager of Operations in the Rapid Prototyping Center at the **Milwaukee School of Engineering**.

A survey conducted by Colorado-based consulting firm **Wohlers Associates** shows that the consumer-products and automotive sectors spent the most money on rapid prototyping equipment in 2006, but a slew of other sectors are actively buying and utilizing the technology.

"Over the years, I have met rapid-

technology users from a large variety of industries, such as aerospace, medical/dental, consumer, and military. I am always amazed at the various ways they use the technologies. It is interesting to share knowledge and experiences with the different industries," said Doug Mitchell, Development Engineer, **Ford Motor's** Design Components & Scheduling Department.

Following nearly 20 years of research, development, and usage, the additive-fabrication industry is giving subtractive processes—like machining—a run for the money. "The additive fabrication industry has had an average annual growth of 23% over the past three years," said Terry Wohlers, Principal Consultant and President of Wohlers Associates.

Spurring the sales meter into the red-hot zone is 3-D printers. Wohlers Associates estimates that 3-D printer sales totaled \$114 million in 2006, up 17% from 2005. "The additive fabrication industry's growth has been extraordinary, and it's being driven by 3-D printing, which accounted for 73% of all additive systems sold in 2006," said Wohlers.

A pioneer in 3-D printing is Israel-based **Objet Geometries**. The company's patented Polyjet process produces fully cured models via an inkjet head that slides back and forth along the X-axis depositing an ultra-thin layer of the company's propri-



This clutch assembly, produced on a fused-deposition modeling machine from Stratasys, enabled an automotive supplier to identify and fix problems during concept design.

etary photopolymer materials onto the build tray. "We have a breadth of applications for the automotive and a number of other industries, including medical, consumer products, consumer electronics, shoes, toys, and jewelry," said Stephanie Checchi, Marketing Communications Manager for Objet Geometries' U.S. office, which opened in January 2007.

**Z Corporation's** product line includes 3-D portable scanners and 3-D printers. "We can print in full 24-bit color. We literally print a binding agent onto a build powder to produce parts used for a range of applications, including concept models and functional prototypes for the automotive and other industries," said John Kawola, Executive Vice President of Sales, Marketing and Business Development for Massachusetts-based Z Corporation.

The Formiga P 100, which is expected to record its first North American customer installation in the third quarter of 2007, is a plastic laser-sintering machine from **EOS** that can produce walls as thin as 0.016 in (0.41 mm). "In building the Formiga P 100 machine, we took advantage of our own technology. Twenty-three of the machine's components—including the powder funnel, control-switch housing and infrared sensor housing—were laser-sintered by EOS technology," said Alexander Dick, Applications Engineer for Plastic Laser Sintering at EOS.

Ohio-based **Morris Technologies** is considered the world's largest service provider of Direct Metal Laser Sintering (DMLS) parts and inserts. "We see a tremendous interest in using this technology in the aerospace, medical, dental, and automotive industries. In many instances, we're building part geometries that simply cannot be made any other way," said Greg Morris, Chief Operating Officer of Morris Technologies. DMLS parts can be made from metals ranging from stainless steel to cobalt chromium and titanium. "New nickel-based alloys are in development, and other metals—such as aluminum—will be considered for DMLS usage in the near future," said Morris.

Another rapid prototyping process gaining users is fused-deposition modeling. The process is a popular choice in the automotive industry since parts can be made from production-grade thermoplastics, such as ABS, polycarbonate, polycarbonate/ABS blend, and PPSF (polyphenyl-



A scale model (shown) was produced for Germany's DaCar, an automotive company, via an Objet Eden 3-D machine. Once printed, the vehicle was painted to specifications.

sulfone). "If you're going to build a prototype, it's important to build that part in the material that's later going to be used in production," said Darin Everett, Senior Sales Executive with Minnesota-based **Stratasys**.

The ability to grasp a part's form, fit, and function is an important aspect of prototyping. "We do a lot of rapid prototyping of interior, exterior, and underhood parts that must match much of the criteria of a production part, because that's what's needed for product design approval," said Thomas Sorovetz, Supervisor of the Rapid Prototype Development Wood/Computer Numerical Control, Plastic Shop for Vehicle Build and Shop Services at **DaimlerChrysler**.

Approvals can also put a rapid-technologies process on the fast track. Electron beam melting (EBM), a powder-based direct-metal process, is inching closer to getting usage certification from the **U.S. Navy**. "The Navy needs small quantities of replacement parts for aging aircraft. Because molds and dies are not necessarily available anymore, EBM would enable the fabrication of these replacement parts without tooling," said Denis Cormier, Associate Professor of Industrial and Systems Engineering at **North Carolina State University (NCSSU)**.

The first EBM machine was purchased in 2003 by NCSU. "EBM has been commercially available for only three or four years, and as such, the process has now matured to the point where it is finding applications in the real world," said Cormier, adding, "Racecars are one example of being a good fit for EBM because the quantities of parts needed are

small and this process can quickly produce parts without the need for tooling."

Even though rapid technologies continue to gain users and applications, a stumbling block remains. "Today, many consumer products are blister-packed by a thermoforming process. But if we said, 'Let's injection-mold that,' it wouldn't work because of the thin wall of the blister pack. Yet we wouldn't conclude that injection molding is a bad process," said Scott Schermer, Senior Rapid Prototyping Specialist at **S.C. Johnson & Son**, whose consumer products include Ziploc storage bags and Pledge furniture polish.

"The point with rapid prototyping is we don't design to the needs of the technology. Designers and engineers from every industry expect rapid prototyping to fit into our existing knowledge of manufacturing processes," said Schermer. In the future, more design and engineering college graduates will have knowledge about rapid manufacturing techniques.

"We've assisted more than 70 higher-education institutions in establishing rapid-technologies training as part of their pre-engineering and technician education programs. Rapid prototyping, rapid tooling, direct digital manufacturing, and reverse engineering are among the rapid technologies that are being adopted by industries, including automotive, at a quicker pace than was the case in previous years," said Ken Patton, Dean and Principal Investigator for the National Center for Rapid Technologies at **Saddleback College** in California.

*Kami Buchholz*

## Solution in suspension: developing MagneRide

**Delphi** is developing the next generation of its MagneRide magneto-rheological (MR) damper technology, with particular emphasis on its application to more European models. It is being designed as a single component that will provide an OEM with the ability to offer a broad spectrum of ride/handling suspension tuning, from racetrack to boulevard, for diverse vehicles built off the same platform. Delphi is confident that within one vehicle generation, the necessity to choose between high-level ride and handling performance will be virtually eliminated.

Entering production five years ago, initially for the **Cadillac** Seville STS and **Chevrolet** Corvette, the latest iteration of the system is fitted to the **Ferrari** 599 GTB Fiorano, **Audi** TT and, from this year, the Audi R8. "The strength of MagneRide is that it has a very wide range of authority. Our focus now is to increase this even further, providing a 'softer soft and harder hard,' so that the need for compromise is reduced," said European Advanced Ride Systems Manager, Olivier Raynaud. "To achieve this, we are working on a range of enhancements that will be gradually introduced over the next few years."

The aim is to achieve something the auto industry has had very high on its wish list for decades: excellent dynamic performance without compromising ride quality.

MagneRide consists of four monotube dampers, a sensor set, and an onboard electronic control unit (ECU). The MR fluid used in the dampers is a suspension of

magnetically soft particles—easily but temporarily magnetized—in a synthetic hydrocarbon base. When the coil in the damper piston is not energized, the MR fluid flowing through it is not magnetized. The magnetically soft particles within the fluid are randomly dispersed and the fluid behaves like conventional damper fluid. However, when the coil is energized, the magnetic field causes the particles to align into fibrous structures in the direction of the magnetic flux.

The strength of the bond between the particles in the structures is proportional to the strength of the magnetic field; changing the current provides real-time variable damping with a very large range of forces. The result is a system that Delphi describes as having a broader damping range and more-rapid response than conventional variable damping systems without the use of complex electro-mechanical valves. Such capability is particularly appropriate for high-performance cars, especially those used on demanding European roads.

Delphi is now planning to extrapolate the technology further, with its European advanced development team based in Paris—supported by other Delphi technical centers worldwide—focused on delivering a higher dynamic range and a faster transient response. This would allow MagneRide to take more control of the suspension, reducing the authority of the roll bar and springs (which both create ride compromise) and more effectively controlling transient body motions without additional systems. The ability to generate high control forces at a low relative

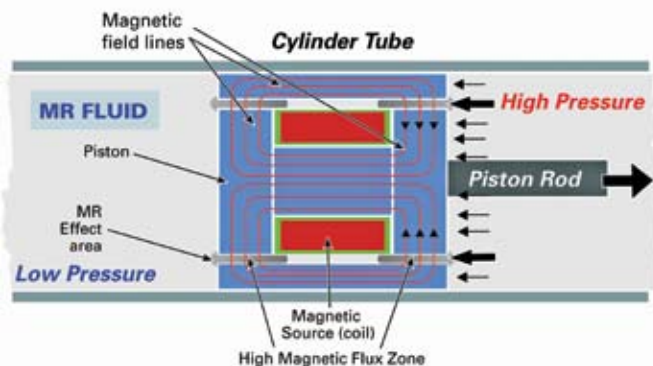
body velocity—the speed the body moves up or down on the suspension—is an intrinsic property of the MR system.

Central to achieving these aims is more-precise control of the magnetic field. To achieve this, Delphi is working to further improve sensing and data processing; to introduce a more-powerful ECU to allow more data to be processed more accurately; and to make refinements to the damper and improve its mechanical characteristics. Current production MR systems use standard wheel-position sensors, but more sophisticated types are being evaluated. Future systems will also take advantage of the growing amount of data available on the CAN bus; information on steering angle, brake pressure, yaw rate, and engine torque could provide a cost-effective source to give the MagneRide system's ECU more comprehensive data on the dynamic environment at a given moment.

The Delphi development team is not just focusing on electronics; mechanical improvements to the dampers include further friction reduction and other modifications to improve resistance to side loads. These improvements will push the application possibilities into heavier vehicle sectors, such as large high-performance SUVs.

Raynaud said that Delphi saw considerable potential for the system to help deliver premium ride and handling alongside excellent off-road ability, with significantly greater packaging flexibility than today's alternative technologies. He added that in order to take full advantage of these mechanical advances and provide even faster control signals, Delphi was also working on more precise control algorithms. He explained that a new data-processing method was now under devel-

**Cross Section of MagneRide Actuator**



Delphi claims its MagneRide damper system is the only semi-active production suspension technology to have no additional moving parts.



The new-generation Audi TT was launched with a version of MagneRide as a suspension option.



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"We are working on a step-change in the capability of ride-control systems," said Delphi's Alex Alexandridis.

opment to replace traditional table-based interpolations with real-time force-generation models that described the behavior of the damper through a series of algorithms.

Delphi could add variables to match the requirements of vehicle manufacturers and their applications, and the system would "understand" the way in which these variables interacted with other parameters to influence flow characteristics and force generation, so facilitating greater optimization of the control signal.

Raynauld also suggested that the next-generation system would have sufficient tunability to allow a single component set to deliver the appropriate ride/handling balance and brand characteristics across diverse vehicles built off a single platform. "We can now provide everything from a

racetrack feel through to limousine comfort just by installing a new calibration," he said. "This gives vehicle manufacturers tremendous opportunities to deliver exactly what their customers want while also simplifying their manufacturing and logistics."

Delphi's Chief Engineer, Chassis Technologies, Alex Alexandridis, added: "Together, these developments allow significant improvements in both vehicle dynamics and ride quality without any increase in packaging or weight compared with today's production system. We are working on a step-change in the capability of ride-control systems. Within one vehicle generation we will virtually eliminate the need to choose between ride and handling performance."

Stuart Birch

## Autoliv designs SUV airbags

**Autoliv** has revealed two new airbag applications specifically for Sport Utility Vehicles (SUVs): the Front Edge Airbag designed to mitigate the effects of an SUV colliding with a pedestrian, and the Bumper Airbag, which addresses the problem of such high-hood vehicles colliding with passenger cars.



Autoliv is enhancing SUV safety systems to better protect pedestrians and smaller vehicles.

"The fatality risk for pedestrians is 2.5 times higher in SUV impacts than it is for regular cars," stated Autoliv, when announcing new developments at the Enhanced Safety of Vehicles conference in Lyons, France. "Another difference is the impact area. While most pedestrians killed by passenger cars perish when they hit their heads on the hood or windshield area of the car, the majority of severe injuries to pedestrians caused by SUVs occur when the front hood edge hits the pedestrian's chest and abdomen. Autoliv has therefore developed an airbag to address this problem. Triggered by a pre-crash sensor (such as radar), the airbag

deploys a few milliseconds before a pedestrian impact."

The company explained that the system had been tested in both computer simulations and in real crash tests, involving crash dummies representing an average male and a very short female. In the simulations, the Front Edge Airbag had demonstrated its ability to pass EuroNCAP requirements. In the full-scale tests, the airbag had decreased all critical-injury values "considerably," the largest reduction being for the abdomen of the male dummy. Injury risk was reduced from 99% to only 3% when using the Front Edge Airbag. The test velocity was 40 km/h (25 mph), described as being the average impact speed in fatal pedestrian accidents.

"Based on the crash tests, it is estimated that this new airbag could save hundreds of lives every year in the United States alone," stated Autoliv.

The Bumper Airbag for SUVs also enhances pedestrian safety by deploying from beneath the bumper to protect the pedestrian's legs. "In tests, the violence to the lower legs of the pedestrian dummy was reduced by more than 50% to levels within the criteria set by the EuroNCAP rating agency in their pedestrian protection tests," revealed Autoliv.

"However, the most important application of the bag will probably be in crashes when there is a mismatch in the height of the vehicles, especially when an

SUV or other high-profile vehicle 'T-bones' a passenger car. In these side-impact collisions, the front of the SUV typically hits above the sill and the energy-absorbing structure of the passenger car, resulting in critical intrusions into the passenger compartment and, in some instances, even collapse of the protection cage around the car's occupants." Crash data indicated that the risk of death in such crashes was between 27 and 48 times higher in a passenger car than in another SUV, according to Autoliv.

The 1.5-m (4.9-ft) long, tubular Bumper Airbag has also been evaluated in computer simulations and real crash tests. Mounted under the bumper of a **Ford Explorer** that was run head-on into the side of a typical passenger car at 48 km/h (30 mph), the bag inflation started 80 milliseconds before the impact, using a pre-crash sensor, and the bag's load-carrying structure swung into position.

"The intrusions were significantly less at all measuring points with the Bumper Airbag. At the level of the head of an occupant, the reduction was as much as 40%. An added benefit indicated by the tests was that the time available to inflate the side airbags of the passenger car could be increased when the SUV is equipped with a bumper bag," stated Autoliv.

Stuart Birch