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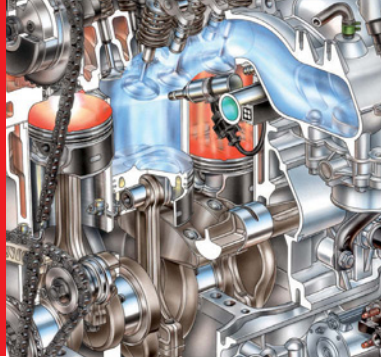
Top new engines
Latest internal combustion highlights



Chrysler 300
Taking center stage in Detroit

SAE International

2011 SAE President
Cummins exec seeks continuity

Riding comfortably
Suspensions for in-wheel motors

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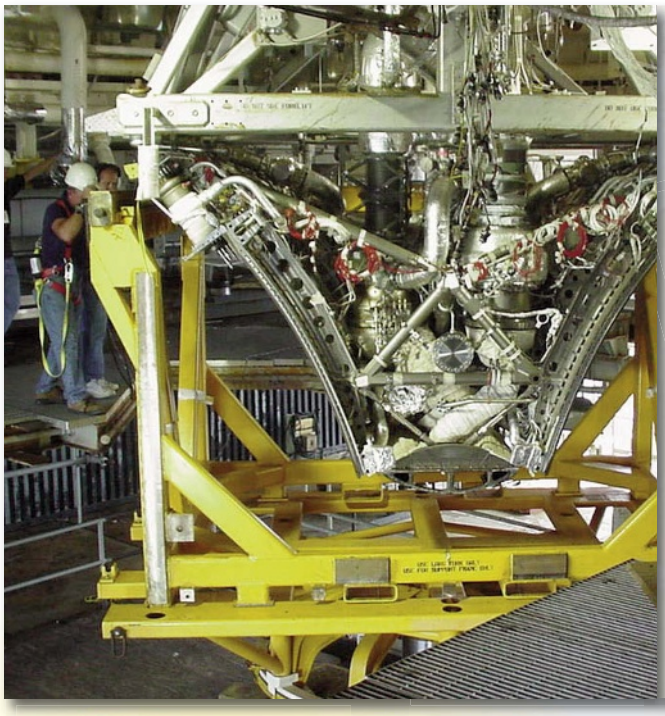

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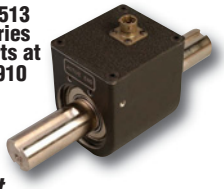

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automotive
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features

cover

Based on a new second-generation, rear-wheel-drive E-segment chassis architecture, the 2011 Chrysler 300 is said to deliver best-in-class V6 power thanks to the new 3.6-L Pentastar engine.

regulars

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Virtual prototyping platform

ESI's Visual-Environment 6.5 features an integrated and versatile virtual prototyping platform for improved productivity. More detail at www.sae.org/mags/aei/9253

Motor controller unit

Mitsubishi Electric integrated a motor and controller into the world's smallest and lightest motor controller unit for electric power steering in automobiles, according to the company. More detail at www.sae.org/mags/aei/9255

Control IC for headlights

Renesas Electronics' control IC for automotive LED headlights provides an integrated current-control function for constant-current drive of up to 12 power LEDs connected in series and a predriver function for driving external metal-oxide-semiconductor field-effect transistors (MOSFETs). More detail at www.sae.org/mags/aei/9282

TOP NEWS

TRW Automotive Holdings Corp. has secured several contracts for the supply of electric power steering (EPS) systems to domestic Chinese vehicle manufacturers, with the first launch scheduled as early as 2012. TRW will supply its Column Drive EPS system for multiple platforms with four domestic manufacturers initially. More detail at www.sae.org/mags/aei/9304

Ford Motor Co. will add 750 salaried engineering jobs in product development and manufacturing between this year and next in the U.S., with a focus on engineers specializing in batteries, system controls, software, and energy storage to work on electric vehicles. More detail at www.sae.org/mags/aei/9296

The **U.S. Department of Transportation**'s **National Highway Traffic Safety Administration** has adopted a new rule under which automakers must phase in, beginning Sept. 1, 2013, technologies (envisioned as larger and more robust curtain airbags) that prevent passenger ejections through side windows. More detail at www.sae.org/mags/aei/9325

Toyota is launching a new, advanced safety research center at its tech center in Ann Arbor, MI, that will collaborate with leading North American universities, hospitals, research institutions, federal agencies, and other organizations on projects aimed at reducing the number of traffic fatalities and injuries. More detail at www.sae.org/mags/aei/9305

WEBCASTS

Weight and cost-reduction strategies

An hour-long webcast titled "Weight and Cost Reduction Strategies for Tomorrow's Vehicles" is now available for free on-demand viewing on the SAE website. The program's experts examine how engineering thermoplastics can help OEMs meet weight-reduction targets while increasing vehicle performance and reducing costs. Speakers are Dr. Matthew J. Zaluzec of **Ford** Motor Co.'s Research and Innovation Center, Hansel Ramathal of **Ticona Engineering Polymers**, and Marco Barbolini of **Röchling Automotive** AG. View at: www.sae.org/webcasts.

Material solutions to downsize engines

"Turbochargers and Emissions Systems: Material Solutions to Help Downsize Engines" is a free 60-min webcast that explores high-performance, lightweight materials for use in air-induction components such as turbochargers, hot- and cold-side ducts, resonators, charge air coolers, and emissions systems. The webcast is available for on-demand viewing on the **SAE** website and features a panel of **DuPont Automotive** application development experts. View at: www.sae.org/webcasts.

Renewably sourced engineering polymers

"Renewably Sourced Engineering Polymers for the Automotive Industry" is a free webcast that focuses on OEM sustainability goals in the development of eco-friendly cars. This 30-min program, which provides an overview of **DuPont**'s bio-based technology platform, polymer properties, and applications in the automotive sector, is available for on-demand viewing on the **SAE** website. View at: www.sae.org/webcasts.

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40 (mpg) is the new 30

In the U.S., the pressure on OEMs to improve fuel economy is coming from new government regulations and renewed consumer concerns about the rising price of gasoline. The **U.S. EPA** (Environmental Protection Agency) and **NHTSA** (National Highway Traffic Safety Administration) have an aggressive timetable for implementing new emissions and Corporate Average Fuel Economy (CAFE) rules including a fleet-averaged 35.5-mpg combined city/highway fuel economy to be phased in by 2016. The price for gasoline has pushed past the $3/gal mark, and consumer demands for fuel efficiency are expected to strengthen as prices rise.

Although hybrid and electric vehicles are expected to help satisfy some of the governmental and market demands, it is the conventional (primarily gasoline) models that are expected to make the greatest contribution to fleet efficiency. Rising expectations are refocusing the industry's technical minds from the old 30-mpg EPA highway benchmark to 40 mpg and beyond.

In January, **Chevrolet** announced that fuel-efficient cars and crossovers drove its 2010 sales 16% higher. Its most fuel-efficient U.S. gasoline model, the Cruze Eco, delivers up to 42 mpg EPA highway. The smaller Sonic, revealed at last month's auto show in Detroit and on sale in the fall of 2011, will also offer up to 40 mpg.

When **Hyundai** revealed its 2011 Elantra at the 2010 LA Auto Show in November, it stressed that all models of that car (automatic and manual) attain the 40-mpg EPA highway number. The new car is also 18% more fuel efficient than its predecessor.

Not to be outdone, **Ford** announced late last year that it will add its fourth nameplate (including the hybrid Ford Fusion and **Lincoln** MKZ) in 2011 with 40 mpg or higher fuel economy—more than any other full-line manufacturer, it says. The Fiesta SE with SFE package (40 mpg highway) will be joined early this year by the new 2012 Focus in Ford's 40-mpg club.

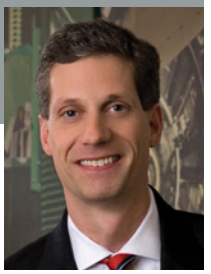
So how are the automakers beating some hybrid models in achieving such highway fuel-economy heights? Two recent examples highlight the latest drive for efficiency.

For the Cruze Eco, **General Motors**' engineers focused on aerodynamic enhancements, mass optimization, and powertrain efficiency. The heart of the car's efficiency is its turbocharged 1.4-L Ecotec, which we highlight in this issue (p. 22). A 0.298 coefficient of drag contibutes about 6 mpg to the 42-mpg highway number. Mass was reduced from 3223 to 3009 lb (1462 to 1365 kg) vs. the Cruze 1LT by speccing smaller weld flanges, reduced sheet-metal thickness, and lighter wheels/tires. The car's six-speed manual transmission gets a "taller" sixth-gear ratio for reduced highway engine rpm.

World-class weight efficiency was one of the program targets for the Elantra engineering team, with Hyundai claiming a manual-transmission model mass of 2661 lb (1207 kg). Company engineers and designers worked hard to shape the new Elantra for efficiency, fine-tuning it to an impressive 0.28 coefficient of drag, while targeting many other areas of the vehicle. The company attributes major efficiency improvements to the car's Nu 1.8-L engine vs. Beta 2.0-L engine (7.4%), six-speed vs. four-speed automatic transmission (4.1%), smart alternator (2.5%), low-rolling-resistance silica tires (1.4%), mass savings (1.8%), and reduced coefficient of drag (0.5%).

Top automaker executives are expressing greater confidence that their companies will meet the 2016 CAFE fleet-averaged 35.5-mpg combined city/highway fuel economy. However, the biggest challenge may be yet to come. NHTSA and EPA, working with the **California Air Resources Board**, are expected to issue a final rule on MY2017-2025 CAFE standards sometime this year.

Kevin Jost
Editorial Director



A solid plan for success

Sustainability and growth—two words that are crucial for **SAE International**'s ongoing success.

These also are two words that define the society's 10-year strategic roadmap, which builds the pathway to achieving SAE International's Vision 2020. The roadmap establishes organizational goals designed to reinforce the value of SAE International membership; expand SAE International's information-based products; diversify product offerings across and throughout the mobility industry (including aerospace, automotive, and commercial vehicle); capitalize on emerging technologies; and deliver globally viable product offerings.

During 2010, SAE International's Board of Directors and executive team developed the 10-year strategic roadmap and established the goals and the tactics to achieve Vision 2020. During this process, the Board of Directors reaffirmed the society's mission statement and core strategies.

SAE International is a global body of scientists, engineers, and practitioners that advances self-propelled-vehicle and system knowledge in a neutral forum for the benefit of society.

While the SAE International of 2011—and beyond—in some ways will look similar to how it looks today, it also will look very different. A disciplined approach will enable the organization to significantly invest in new programs, products, and services that better reflect the transforming needs and expectations of all constituencies. Strengthening its global operations will further enhance SAE International's ability to deliver a locally relevant portfolio in an affordable manner. And, a more dynamic operating structure will permit SAE International to better respond to a diverse and changing marketplace.

The strategic roadmap uses a multi-year approach, with near-, mid-, and long-term goals and objectives. Of course, along the way, metrics and measures will show how well SAE International is doing with regard to achieving the stated goals.

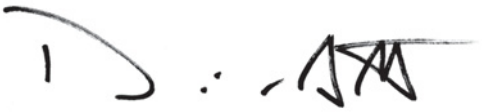
Some of the goals and highlights include:

- Expanding and enhancing the tiered-membership program, EngineerXchange, and introducing a new Member Rewards Program
- Offering the world's largest and most comprehensive English-language, full-text, online database of mobility engineering information
- Ensuring the global relevance and availability of SAE International technical standards and developing new conformance programs in the areas of industry interest and support
- Providing the highest-quality and most timely meetings and conferences in a variety of formats (face-to-face, virtual), showcasing the latest intellectual property and technology trends
- Developing new professional development content and programs on critical technologies, both domestically and globally
- Identifying emerging sectors to be served by SAE International and developing programs, products, and services to serve them.

These are just a few of the goals outlined in the strategic roadmap. It is an ambitious plan, but it is a plan that is crucial for the continued success of SAE International as we serve the mobility engineering industry.

An old Chinese proverb states, "It is better to take many small steps in the right direction than to make a great leap forward only to stumble backward." That's sound advice…for business and beyond. The 10-year strategic roadmap outlines the steps needed for this organization to better serve its members and our industry and academic institutional partners and, most importantly, advance knowledge and information for mobility engineering professionals.

Periodically throughout the coming year, this column will focus on some of the strategic objectives outlined in the plan, showing how each helps to make Vision 2020 a reality.



David L. Schutt
SAE Chief Executive Officer

Testing

DIS makes 3-D measurement possible in climatic extremes

The ability to pinpoint a product's dimensional profile before and after exposure to temperature and humidity extremes is a standard testing practice, but the ability to measure a component's shape during exposure to harsh conditions is a new option.

ChamberCam from **Dynamic Intelligent Solutions** (DIS) uses photogrammetry hardware and software to measure in real time what happens to a part during thermal cycling in an environmental chamber.

"Many times during testing under extreme climatic conditions, a part's shape/dimensions will react in ways that engineers can't detect, making it difficult to pinpoint what the root cause may be when a part fails or becomes dimensionally unstable," said Jim Arnone, Managing Partner of DIS, a Clinton Township, MI, company. "Our patent-pending ChamberCam process takes already proven optical measurement equipment and places it in the chamber during extreme climatic testing to capture the part's dimensional data.

"This process provides more information than a conventional method, as well as previously unobtainable data, and that potentially eliminates days or weeks of costly testing, development, and downstream engineering time."

The conventional way to check the dimensional stability of a part is on a coordinate measurement machine (CMM) before and after the climatic test. But the ChamberCam process, which employs **Aicon 3D Systems** software for point data and analysis as well as 15-Hz resolution cameras, makes it possible to measure a part dynamically throughout a climatic test.

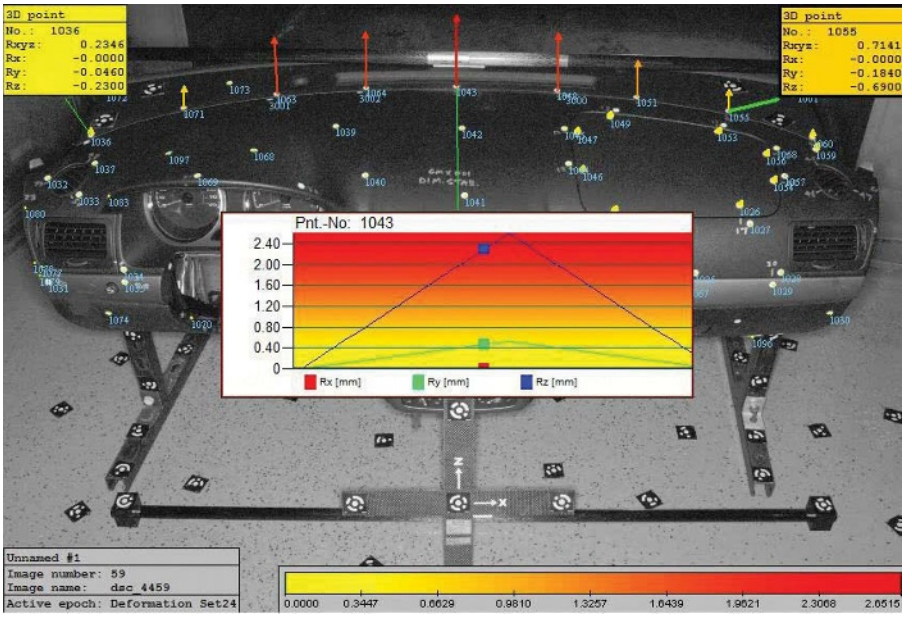
"The biggest challenge was finding a way to keep each camera operable inside the environmental chamber at a high temperature of 177°C and a low temperature of -77°C and up to 95% relative humidity. To do this, we have an external chiller source feeding coolant to the housing around each camera that's located inside the environmental chamber," explained Arnone.

Instrument panels, door panels, headliners, armrests, visors, and other interior parts are the initial targeted components for the ChamberCam process. However, any part or assembly that is sensitive to temperature and humidity is a possible match for the measurement technique that is accurate up to 45 µm (1772 µin) and can capture data up to 15 times per second.

Testing specialists can use the ChamberCam system to address a variety of tasks, including geometric dimension and tolerance measurements, deformation analysis, motion and position analysis, dynamic process acquisition, and precise digitizing of medium- to large-sized objects.

"We're able to provide time, temperature, and humidity data to the customer in a variety of formats, including pictures, charts, video, and 3-D point data," said Arnone.

Kami Buchholz



This screen capture shows how the changing measurement data is displayed over the actual instrument panel being tested.

Materials

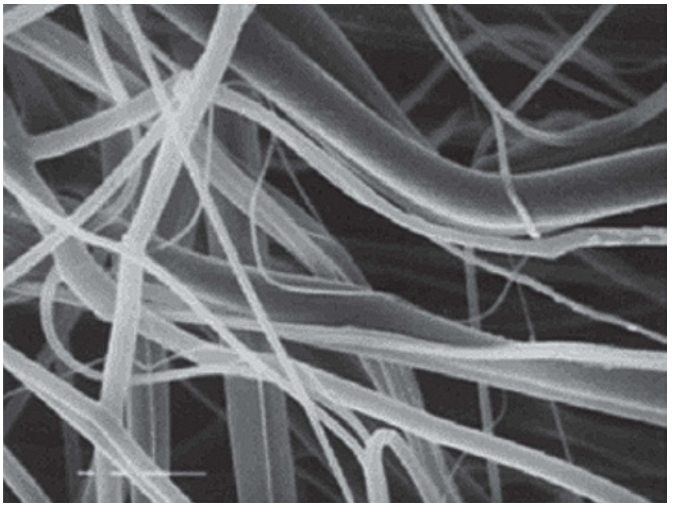
Lightweight acoustic material from 3M makes hybrids more refined

3M worked closely with automakers on some recent hybrid programs, including **Toyota**'s Prius and Auris and **Honda**'s CR-Z. Now the technology company plans to bring its expertise and specially developed versions of Thinsulate material to Europe via its recently formed European Automotive Acoustics Group.

"The early adopters buying these cars expect hybrids to provide an efficient, premium driving experience with superior refinement," said the head of the new group, Abs Master. "Balancing the weight and performance of the car's acoustic package…requires lightweight materials optimized to manage the higher range of frequencies."

He noted that 3M's Thinsulate can effectively absorb the higher-frequency sounds produced by hybrid vehicles' electric motors and transmissions. The material is said to be lightweight, compact, and compressible for ease of packaging and assembly.

3M was reluctant to provide specifics about the specially developed material since Thinsulate is not patent-pro-



The mesh of fibers in the specially developed version of 3M's Thinsulate material absorbs the higher-frequency sounds produced by hybrid vehicles' electric motors.

tected and there are some trade secrets in the manufacturing process. Thinsulate is a mix of polypropylene, which provides the high-frequency noise absorption, and polyester, which makes the material compressible.

"Standard Thinsulate was a very good starting point and so development was really a process of fine-tuning the material for the application," a company spokesman told **SAE** Magazines. "For the hybrid grade, 3M does one or two clever things with the polypropylene content to fine-tune its high-frequency noise absorption."

The company expects the material solution to be particularly useful for vehicles that are based on platforms for which a hybrid version was not originally planned.

Abs Master, head of 3M's European Automotive Acoustics Group, said: "Thinsulate can already be found in every single Japanese hybrid. Interest from European manufacturers is strengthening, too."

The original Prius was the first hybrid to use the material.

Applications of Thinsulate have included door panels, headliners, wheel wells, pillars, and instrument panels. For hybrids, it is used in the same locations but also can be applied around hybrid-specific parts such as electric motors, power electronics, etc.

The material replaces mixed-fiber shoddy mats, foams, and absorbers, reducing the weight of some acoustic-material parts by up to 40%, or "several kilos," the company claims.

"It's more cost-effective rather than lower-cost," the spokesman said. "It depends on the application to an extent. If a vehicle has been modified to run as a hybrid, it is considerably less expensive than redeveloping the acoustics package using conventional sound-deadening materials. Because Thinsulate is also easier to attach and requires less packaging space, it is often more cost-effective than trying to work with conventional materials. You need a lot of shoddy to mask high-frequency noises."

Thinsulate comes die-cut with slits so that it can fold and conform easily around the contours of the vehicle.

The material is available in the U.S., and 3M is already in talks with U.S. manufacturers, according to the spokesman.

Other transportation sectors are suitable outlets for the material as well, with current applications in off-highway and commercial vehicles.

"Its thermal insulation properties are making it an attractive option for applications such as lining cabin walls," the spokesman said. "New regulations that stop drivers from idling their engines to heat the interior at night make this a growing issue for the industry."

3M also has a range of acoustic solutions for aerospace and is reportedly talking to companies about applications in which Thinsulate could be used to absorb high-frequency noises.

Ryan Gehm

Energy/Environment

GM, LG Chem license Argonne chemistry for next-gen lithium batteries

The next-generation of **General Motors** electrified vehicles may be "powered by Argonne"—at least as one key aspect of their battery-cell chemistry is concerned.

On Jan. 6, GM and the **U.S. Department of Energy**'s (DOE) **Argonne National Laboratory** announced a global licensing agreement that allows GM to use Argonne-patented cathode material technology in its lithium-ion batteries for electrified vehicles. Argonne also licensed the technology to GM's incumbent battery-cell supplier, **LG Chem**, to manufacture and use in its Li-ion cells.

The Argonne technology was described by Eric Isaacs, Director and President of **UChicago Argonne** LLC, as "a layered/layered composite" that combines lithium- and manganese-rich mixed-metal oxides. UChicago Argonne is a wholly owned laboratory management subsidiary of the **University of Chicago**.

Isaacs told a media teleconference attended by *AEI* that the cathode material has the potential to significantly improve the performance of lithium-type automotive batteries. It can extend a battery's energy density by a factor of two, and potentially it will enable vehicle charging at higher voltages (leading to greater energy storage capacity).

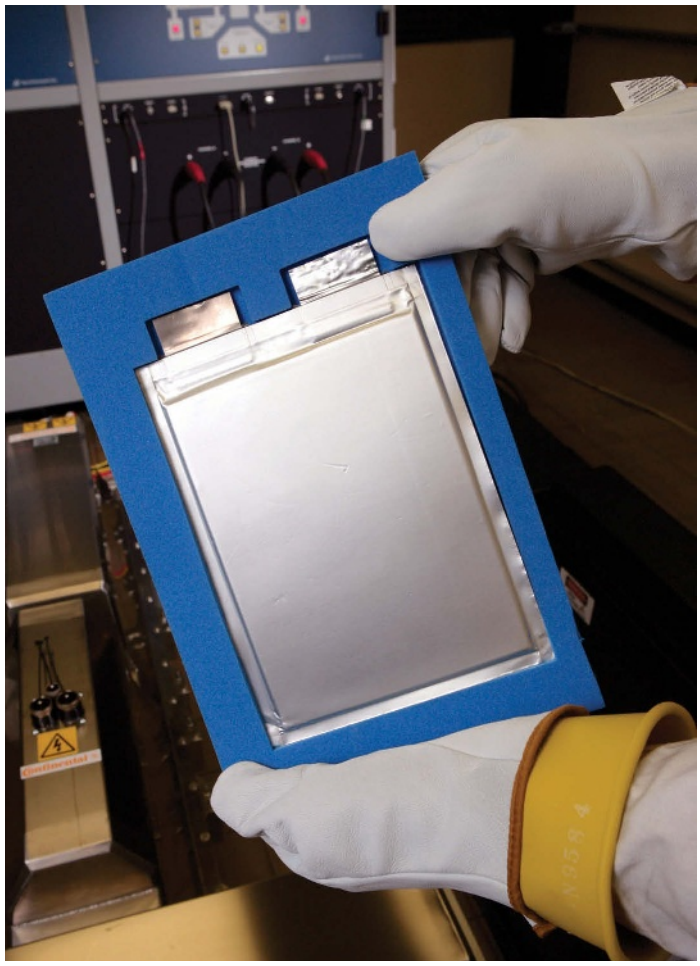
The Argonne chemistry also can increase battery calendar life and ensure greater safety of Li-ion cells. Isaacs said the cathode material has been in development at the Illinois facility for about 10 years.

"This is the most capable cathode material of all the many we've looked at," commented Jon Lauckner, the President of **GM Ventures** who is known as the "godfather" of the **Chevrolet** Volt. "We believe it can be the basis of the next-generation cathode."

While Lauckner described the intellectual property surrounding the cathode material as "very promising," he cautioned that significant development work and evaluation is still to come before the chemistry is production-ready. He did not forecast when that would be.

His caveats are shared by Mohamed Alamgir, Research Director of LG Chem's **Compact Power** Inc. division that developed the Volt cells for production.

"We're licensing a very broad patent portfolio of layered materials," he explained in an interview with *AEI*



An LG Chem/ Compact Power prismatic type lithium cell as used in the 2011 Chevrolet Volt. Argonne's new layered/layered manganese-rich composite cathode material could obsolete this incumbent technology in most if not all metrics.

following the teleconference. "They have high voltage potential," up to 4.5-4.7, he noted.

The Argonne technology could spur all-new lithium cell chemistries, with new anode and electrolyte chemistries, and significantly improved performance compared with the spinel/layered makeup of the current cathode in the Volt's Li-ion manganese-spinel ($LiMn_2O_4$) prismatic cells, said Alamgir.

If GM and other OEMs who license the Argonne cathode chemistry—it's not an exclusive-use license, Isaacs pointed out—decide to architect future battery cells with it, LG Chem is ready to adopt a new and equally vital role in the automotive battery supply chain. Where it currently provides all the cell intellectual property on Volt and the 2012 **Ford** Focus EV (to cite two early automotive customers), as well as development, testing, and productionization, the company would primarily take over the latter three functions regarding new cells using the Argonne cathode, Alamgir explained. (LG Chem continues to develop its own advanced lithium cell chemistries for automotive use.)

"The national labs are not manufacturers," Alamgir observed. "They generally work with small quantities of the materials. And they don't have the interest or experience for the extensive development and testing [of new cells] in all conditions, in various power sizes, and in the high volumes required for the automotive environment. Our job would be to 'tailor' both the anode and cathode chemistry for the new cell. We'll develop and improve it," he said.

LG Chem's Compact Power group tested the first-generation Volt cells for nearly three years leading up to the car's production, he noted.

"The Argonne license is exciting for us, but the technology has a long way to go before it's mature," Alamgir noted. "We've got our work cut out for us."

Lindsay Brooke

Interiors

Schott in the dark for Mini

The days when vehicle interior ambient lighting meant at best the dim glow from instruments and switches are now an equally dim memory. Subtle ambient interior lighting solutions have become de rigueur for many cars across an increasingly broad price spectrum and now form a significant element of interior design.

An example of that is the new **Mini** Countryman. **Schott**, an affiliate of the **Carl-Zeiss-Stifung** (Foundation), has supplied fiber-optic technology for the car, illuminating a central area that stretches from the manual gearshift lever to the rear of the interior between the two rear seats in four-seat configuration or between the front seats in five-seat form.

"Its shape is underscored by the contour illumination option offered by Schott that can be integrated, comprising light guides made of glass fibers inside plastic sheathing that draw their light from LEDs and shine evenly along the entire surface," said Stephan Schabacker, the company's Automotive Business Manager. "They are infinitely adjustable in mixed color shades of orange and blue."

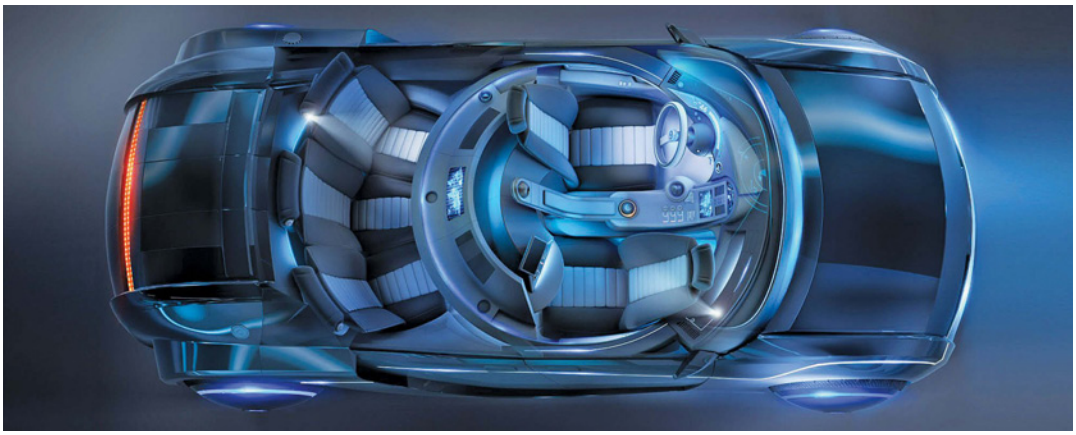
As part of a package option, the Mini's ambient lighting also provides interior door panel illumination.

Schott regards interior ambient lighting as increasingly providing significant delineation between competitors in terms of brand image, notably in the premium and mid-range sectors. Additionally, lighting strips on doors, consoles, or contours offer passengers a sense of orientation, added Schabacker: "Individually adjustable light moods can be of benefit in different driving situations or during long trips and thus contribute towards greater safety."

He also states that unlike conventional LED chains, the hybrid system used in the Mini offers homogeneous light in "nearly every possible color and intensity," even along longer sections: "A special manufacturing technique ensures that the light that is fed in, exits across the entire surface of the fiber. Unlike the lighting technique used in the past, contour lighting is able to glow in a discrete manner without creating reflections, even if there is direct eye contact, so it does not need to be covered after installation."

Special diffusion particles are added to the cable material, which can be dyed to complement specific metallic effects.

Contour lighting of the type fitted to the Mini is described by the company as providing low installation depth, ex-



Schott sheds light on future interior ambient lighting design.

cellent temperature management, long service life, ease of maintenance, and the flexibility of the light guides that Schott regards as virtually any contour and that can be manufactured in a wide variety of profiles.

Schott lists the plus points of its flexible, side-emitting, glass-fiber automotive contour lighting cables as offering homogeneous and evenly distributed light output over a length of several meters; no visible color shift; easy adaptability to a central light engine; design freedom; customized outer appearance in shape and color in non-illumined state; and cost saving because no extra tooling is required.

"We are trying to make completely new and creative lighting solutions that meet respective customers' demands," Schabacker said.

Stuart Birch

Re-engineered Chrysler 300 looks, feels more upscale

"We're guilty of starting this whole beltline craziness," said Ralph Gilles, Senior Vice President of Product Design, referring to the previous-generation Chrysler 300. But with the new 300 sedan (shown), "we actually opened the DLO [daylight opening] a little bit," resulting in 15% better outward visibility.

For the 2011 **Chrysler** 300, "everything is brand new," boasted Olivier Francois, President and CEO of the Chrysler Brand, Chrysler Group LLC, at the full-size sedan's world premiere at the North American International Auto Show (NAIAS) in Detroit.

Based on a new second-generation, rear-wheel-drive E-segment chassis architecture, the 300 is said to provide best-in-class V6 power thanks to the new 3.6-L Pentastar engine. Delivering 292 hp (218 kW) and 260 lb·ft (353 N·m)—increases of 42 hp (31 kW) and 10 lb·ft (14 N·m) compared to the previous 3.5-L—the Pentastar V6 offers an 8% improvement in fuel economy, with **EPA** ratings of 18/27 mpg city/highway.

Also available is the 5.7-L Hemi V8 with Fuel Saver Technology, which transitions to four-cylinder mode whenever possible to deliver up to 20% improved fuel efficiency.

For improved aerodynamics and visibility, the windshield has been raked back 3 in (76 mm) and thinner rolled-framed doors with thinner pillars—enabled by the use of hot-stamped ultra-high-strength steel in the A-pillars, bodyside doors, upper front-rail section, and windshield header—improve outward visibility by 15% compared with the previous-generation 300.

More than 67% of the sedan's lower unibody structure and 53% of its upper structure are stamped from high-strength or advanced high-strength steels (AHSS). AHSS is applied to the vehicle's seat crossmembers and upper-rear cross-car area behind the rear seats. Dual-phase steel is used in the inner-front rails and engine box area. Transformation induced plasticity (TRIP) steel can be found in the B-pillar, lower header, and rocker areas; nylon-composite reinforcements were also used in the upper header cavities and A- and B-pillars.

The rear structure of the new 300 was strengthened by 26% to ensure front-to-rear stiffness continuity.

Despite more extensive use of lightweight materials, the new 300 is 236 lb (107 kg) heavier than the outgoing model—the base model weighing 3961 lb (1797 kg)—due to the addition of new content.

With a 0.320 Cd, the sedan sees an 8% improvement in aerodynamics.

New chassis hardware includes front-suspension hydrobushings, monotube shock absorbers, a repositioned lower-front shock-to-suspension-link bushing, hydroformed steel front- and rear-suspension cradles, and an electrohydraulic power steering system. At the rear, the 300's five-link suspension design features new roll-steer geometry, allowing independent control of camber and toe suspension movement.

Chrysler engineers say the sedan's road-holding capabilities are improved with new camber geometries, set at -1.0° in the front and -1.75° in the rear. New larger-diameter front and rear stabilizer bars are said to help reduce body lean during cornering.

Three suspension tunings and wheel and tire combinations ranging from 17- to 20-in will be available, including an all-wheel-drive (AWD) version that features a 0.5-in (13-mm) tighter tire-to-fender fitment, a 0.15-in (3.8-mm) lowered overall ride height, and 19-in wheels with wider P235/55R19 all-season performance tires. An active transfer case and front-axle disconnect system improve fuel economy by up to 5%. Chrysler claims that no other major automaker offers the combination of these two independent technologies.

The 300C AWD features a multilink front suspension with unique steering knuckles, asymmetrical lower-control arm, and tubular upper-control arm to manage up to 38% of the Hemi V8's power to the front wheels.

According to Francois, the new 300 has "more safety features than any domestic rival," with more than 70 safety and security technologies. New active safety features include adaptive-forward lighting, forward collision warning, and blind-spot monitoring. That list also includes standard Keyless Enter-N-Go and electronic stability control (ESC).

Engineers took several measures to help absorb road noise and quiet the cabin, including two 8-ft (2.4-m) composite underbody panels with acoustic insulation, dual-pane acoustic windshield and front-side glass, body-cavity silencing foam, under-flush rolled-framed doors with triple seals, and acoustic wheel-well liners.

Inside, Uconnect Touch delivers what Chrysler claims is the segment's largest standard touchscreen radio (8.4 in) and offers **Garmin** navigation and **Sirius** Travel Link for real-time weather, fuel prices, etc. The seats include an S-shaped spring suspension, new front seat backs with four-way lumbar system, and variable-density foams applied in the lower seat, seat back, and bolsters.

At the NAIAS reveal, Francois proclaimed that "quality is nonnegotiable." That is why Chrysler engineers tested the 300 for more than 7 million mi (11 million km) during the evaluation phase in its labs, proving grounds, and on public

roads in various climates. That also explains major investments at Chrysler Group's Brampton (Ontario) Assembly Plant, where production of 300 series sedans launched in early January.

Among other investments, a new metrology center was installed at Brampton to measure and validate body geometry. Tools within the metrology center are used to verify the vehicle's entire sheet metal structure to very small tolerances, to identify possible deviations between the product and the process.

The 2011 Chrysler 300 arrives in dealerships this spring, starting at $27,995 (including destination).

Ryan Gehm

Vertrek concept previews 2013 Ford Escape

Ford put its sleek new design language for its global compact utilities in the spotlight at the recent North American International Auto Show in Detroit, rolling out the Vertrek concept. Very similar in exterior form to the production 2011 Kuga sold in Europe, the Vertrek gives North American customers a glimpse of the 2013 Escape, according to engineers.

The all-new Escape (Ford has not yet confirmed the nameplate will be retained) is scheduled to switch to the global C1 architecture, which underpins the 2011 Focus and C-Max, as well as Kuga.

By 2012, the new platform will support 10 nameplates and account for annual sales of more than 2 million vehicles. The new global-C architecture replaces three regional C-segment platforms, dramatically boosting economies of scale.

Very similar in exterior form to the production 2011 Kuga sold in Europe, the Vertrek gives North American customers a glimpse of the 2013 Escape, according to Ford engineers.

The current North American Escape is based on the old CD2 architecture, itself derived from Mazda's GF platform.

According to Derrick Kuzak, the company's Group Vice President, Product Development, approximately 80% of the total bill of materials used by the new common architecture will be shared across regional models.

At a late 2010 reveal of the Vertrek, Vice President of Design J Mays told *AEI* that the concept's overall design is "quite close" to the next-generation production Escape.

At a 178.5-in (4534-mm) overall length, the four-seat Vertrek is longer—by 3.8 in (97 mm)—and wider than the current, boxier Escape. It provides 15% more cargo volume behind the first-row seats than the smaller and taller Kuga, and about 20% more volume behind the second row.

The larger cabin addresses a desire for more interior space by Kuga customers in Europe and the U.K., and will please North American customers used to the larger Escape, Kuzak noted.

Ford product planners see considerable upside in the global compact crossover segment. European demand in the segment has grown 200% since 2000. According to Mays, sales of compact utilities in China is forecast to increase 60% from 2009-11.

Vertrek's raised beltline, compared with that of both current vehicles, reflects design for enhanced side-impact protection. According to Mays, preliminary testing shows the concept to be 5% more aerodynamic than the current Escape's 0.29 Cd. He said Vertrek was developed in Ford's Cologne design center.

Ford engineers said the production vehicle body-in-white is configured to package hybrid propulsion systems and their battery packs. Powertrains for the 2013 Escape are expected to be a base 2.5-L Duratec inline four-cylinder, with 1.6-L or 2.0-L EcoBoost engines optional. In Europe, where 95% of Kuga sales are turbodiesel models, the 2.0-L TDCi diesel and 1.6-L EcoBoost petrol engine are the likely offerings.

The new Escape/Kuga will also feature two- and all-wheel-drive systems, six-speed manual and automatic transmissions, and Ford's new Auto-Start-Stop system, now in production in Europe and in the pipeline for North America in 2012.

According to Kuzak, Auto Start-Stop takes approximately 0.3 s to start the engine. The system can improve vehicle fuel efficiency by up to 10%.

Vertrek also features the company's Smart Regenerative Charging. The system addresses the frequent charge-discharge cycles of start-stop technology. It increases alternator output when the vehicle brakes or decelerates, converting the kinetic energy of the vehicle into electric energy without using additional fuel, providing "free" electric current for battery recharging.

In North America, the 2013 Escape will be built at the Louisville, KY, assembly plant that produced the previous-generation Explorer. The facility is currently being retooled to make the C-segment-based utilities later this year.

Lindsay Brooke

Chevrolet brings a Sonic boom to the global B segment

The 2012 **Chevrolet** Sonic debuted at January's North American International Auto Show in Detroit as the first B-segment passenger car to be assembled in the U.S. It launches later this year at **General Motors**' retooled Orion, MI, assembly plant.

A replacement for the Aveo, the new Sonic aims to make small cars profitable for GM by offering high levels of feature content, a fresh exterior form, and spritely performance and efficiency. It rides on GM's Global Gamma architecture and fits into the automaker's portfolio between Chevy's Spark (Global Mini platform) and C-segment Cruze (Delta II).

"Truncated" rear end design on the Sonic five-door hatch visually pushes the car forward, said GM designer Bryan Nesbitt.

GM Europe and **GM-Daewoo** in Korea shared in the development of the front-drive Sonic's platform. The car will be offered in four-door sedan and five-door hatchback body styles. Competitive targets are the **Ford** Fiesta, **Honda** Fit, and **Toyota** Yaris.

The five-door model intentionally resembles a three-door hatch, because its rear door handles are discreetly located in the C-pillar area.

Compared with Cruze, the Sonic sedan is 11 in (279 mm) shorter overall and 2 in (51 mm) narrower, and it has a 6-in (152-mm) shorter wheelbase. It is also 500 lb (227 kg) lighter.

One of the engineering team's primary goals was to create one of the stiffest body shells in the global B segment, according to veteran GM Engineering Executive Director Jim Federico. The sedan's body-in-white measures 28 Hz in first-bending and torsional performance, he told *AEI*.

The team "pushed the limits of high-strength steel use on this program," Federico added.

The structural rigidity enabled engineers to tune the ride and handling more precisely. Engineers from the Corvette program were involved in development and calibration.

Sonic notchback sedan is 500 lb (227 kg) lighter than Chevy's C-segment Cruze. EPA ratings are not yet completed for the Sonic models.

Sonic's flat-top-frame cradle is a unique design that Federico said optimizes stiffness in the front chassis portion of the vehicle.

Sonic's front suspension comprises MacPherson struts with coil springs and stabilizer bar. The struts include side-load compensator springs for lower-noise operation, Federico said. In the rear, a semi-independent, compound-link-type suspension uses a tubular V-profile torsion beam with gas-charged shocks. Essentially a straight axle without contour, the rear beam-type design optimizes packaging and is claimed to reduce road-induced NVH.

Front and rear tracks are identical at 59.4 in (1509 mm). Wheelbase is 99.4 in (2525 mm). Overall length of the sedan is 173.1 in (4399 mm); the hatchback is 159 in (4039 mm) long. Overall width for both models is 68.3 in (1735 mm), and overall height is 59.7 in (1517 mm). Curb weights have not yet been released.

U.S. **EPA** passenger volume for the Sonic sedan is 90.4 ft³ (2560 L) and 90.6 ft³ (2565 L) for the five-door model.

Sonic's electric power steering (EPS) features a patented wear compensator that Federico said ensures life-of-the-vehicle steering precision by continually adjusting the system interaction with the steering gear. The foundation brakes are front disc/rear drum with four-channel ABS and brake-force distribution. The front rotors are 10.8-in (276-mm) diameter; rear drums measure 9 in (230 mm).

The chassis control package features StabiliTrak ESC with rollover sensor. Road wheel sizes range up to 17 in. GM engineers claim a 34.5-ft (10.5-m) curb-to-curb turning circle with 14-, 15-, and 16-in wheels, and a 36.1-ft (11-m) circle with the 17's.

Sonic's available powertrain for North America matches that of the Cruze. Standard will be the naturally aspirated 1.8-L Ecotec gasoline four-cylinder, its preliminary output of 135 hp (101 kW) and 123 lb·ft (167 N·m) at 3800 rpm. Engineers claim approximately 90% of peak torque will be available from 2400 to 6500 rpm.

Optional will be the turbocharged 1.4-L Family Zero Ecotec estimated at 138 hp (103 kW) and 148 lb·ft (200 N·m) available between 1850-4900 rpm. Both engines are port-injected.

Three transmissions are available: an M26 five-speed manual and 6T30 six-speed automatic with the 1.8 L, and an M32 six-speed manual with the 1.4-L turbo. Final drive ratios are 3.94:, 3.47:, and 3.65:1 with the respective transmissions.

The car's fuel tank capacity is 12.1 gal (45.8 L).

Sonic's telematics suite includes **OnStar** with six months of turn-by-turn navigation. Available features include **XM** Satellite Radio, USB, Bluetooth, and MyChevrolet mobile application with OnStar MyLink vehicle connectivity.

Lindsay Brooke

Bigger is better for new Passat

Volkswagen revealed its U.S.-centric NMS (New Midsize Sedan) in Detroit at the recent 2011 North American International Auto Show, unveiling it as the new Passat with sternly conservative lines but an aggressive value proposition. The company's goal was to slash the car's price tag without undercutting its European appeal as critics complain happened with the U.S-market Jetta.

The Passat looks like it preserved more of the features Volkswagen shoppers expect in its pursuit of a price mainstream American car buyers demand. For example, the new Passat retains the independent rear suspension system of its predeccesor and boasts a multi-adjustable driver's seat, a gauge cluster and information display seen previously in the Touareg, automatic climate control, and a raft of safety features for its starting price of about $20,000. It also employs soft-touch and low-luster materials inside, largely avoiding the abundance of hard plastics that garnered so much criticism in the Jetta.

The new car stretches to 191.7 in (4870 mm), almost exactly the same length as a **Chevrolet** Malibu and falling between the **Toyota** Camry and **Honda** Accord, addressing the common complaint that the old Passat was less roomy inside than its key competitors.

The Chattanooga, TN-assembled Passat offers three drivetrains. The base engine is the company's 170-hp (127-kW), 177-lb·ft (240-N·m), 2.5-L I5 using either a five-speed manual transmission or an optional six-speed automatic. VW's 140-hp (104-kW), 236-lb·ft (320-N·m), 2.0-L I4 diesel is matched to either the manual transmission or the company's dual-clutch automated manual transmission.

The premium engine option will be the 280-hp (209-kW), 258-lb·ft (350-N·m), 3.6-L VR6 engine, which has the dual-clutch transmission as its standard equipment. VW predicts the VR6 will achieve 28 mpg on the U.S. **EPA**'s highway cycle, while the diesel is expected to score 43 mpg.

That rating is particularly surprising considering that the much smaller Golf is rated at 42 mpg highway with the same engine. The difference is due to different emissions control schemes for the two cars, explained Hubertus Lemke, head of technical project management for VW.

The Passat employs a NOx storage catalyst, while the Golf relies on fuel injection and engine management programs to reduce pollution, the latter

Volkswagen used a conservative style it terms "timeless" for the U.S.-market Passat, which it intends to sell in high volume to mainstream American drivers.

approach costing some fuel efficiency, he said. However, the approach used for the Passat is higher-cost. About a quarter of U.S. Jettas are diesels he said, adding that the company expects a similar number of Passat customers to opt for the diesel.

While the new Passat retains similar suspension hardware as seen previously, including a multilink rear suspension, the spring and damping rates and bushings have all been softened in anticipation of the preferences of the new customers, Lemke said. But he insists that, despite improved comfort, the new car preserves the engaging driving characteristics that attracted many VW customers in the past; "We have the same crisp feeling in the new Passat too," he promised.

Similarly, Volkswagen has long been seen as a leader in terms of cabin appointments, an attribute that seemed threatened under the new car's cost-cutting effort. But Lemke said that VW recognized the customer expectation that the Passat's interior should be superior. "The material which you can see and touch and feel must be attractive for the customer," he said.

The company saved money by using a traditional manual hand brake mechanism rather than one of the increasingly common electric parking brake mechanisms, he said. While declining to quantify the amount of money saved by this substitution, Lemke insisted that it was a substantial amount. "We saved a lot," he said.

Also Volkswagen only had a leather-wrapped multifunction steering wheel in the corporate parts bin, but American customers expected multifunction controls even in models without leather, so the Passat team pushed for development of a less costly plastic-rimmed multifunction steering wheel, Lemke said.

Standard equipment even on the base model includes power windows, air conditioning, ambient temperature, CD stereo with Bluetooth phone connectivity, hill climb assist (for manual transmissions), brake assist, electronic stability control, and six airbags.

Options include power seat adjustment, touchscreen satellite radio, leather seats and steering wheel, navigation, fog lights, and keyless start. To attract attention in the increasingly crowded premium audio segment, the Passat is the first car to carry an audio system wearing the brand of the famed Fender guitar company.

Dan Carney

Hyundai offers unique take on coupe with 2012 Veloster

The **Hyundai** Veloster coupe concept launched at the 2007 Seoul Motor Show was aimed directly at potential Gen-Y buyers, and the production version, shown four years later at the North American International Auto Show in Detroit, has stayed true to its original target. The production Veloster purposefully forgoes pure acceleration and aggressive handling in favor of playfulness and utility, while still delivering a driving experience that is "nimble and agile," according to John Krafcik, President and Chief Executive Officer of Hyundai Motor America.

"Veloster isn't about 0-to-60 times; honestly, there are a lot of other cars that will outrun it in a quarter mile," Krafcik said. "That's not the point of this car. We've got Genesis Coupe in our lineup to wave that flag."

Rather than chase additional horsepower, Hyundai engineers opted instead to target weight efficiency and fuel economy.

"We interviewed a lot of **Scion** tC buyers and what we found was they wanted greater fuel economy because many of them are just starting out and fuel economy is really important," said Brandon Ramirez, Veloster Product Manager. "With Scion tC, they weren't happy with that, so that was the number one development target, fuel economy. That's why we selected the 1.6-L GDI to power this vehicle."

The Gamma 1.6-L four-cylinder engine is the smallest Hyundai engine to use gasoline direct injection (GDI), helping to deliver projected highway fuel economy of 40 mpg, exceeding that of the smaller **Honda** CR-Z hybrid (37/39, manual/CVT). Peak output is an estimated 138 hp (103 kW) at 6300 rpm and maximum torque is 123 lb·ft (167 N·m) at 4850 rpm. The engine is paired with a standard six-speed manual transmission or a Hyundai-developed six-speed dual-clutch transmission.

By using steel from its own plant in Dangjin, South Korea, engineers were able to cost-effectively incorporate high-strength steel and reduce weight. Weighing 2584 lb (1172 kg), Veloster is 476 lb (216 kg) lighter than the Scion tC.

"We don't have to have a really powerful engine if we cut weight," Ramirez said. "By cutting weight, that also improves the agility of the vehicle. The other day, John Krafcik drove the latest tuning of the Veloster and a smile came to his face because it's so light and agile. It's a really fun-to-drive vehicle."

The Hyundai Veloster incorporates a unique third door for easy rear-seat access. The passenger-side rear door handle is hidden to maintain the coupe design.
(Matthew Monaghan)

Veloster is based off of the Elantra platform; however, it features a unique rear suspension with integrated rear stabilizer bar dubbed a V-Beam. "It gives you great handling characteristics," Ramirez said.

Additional insight gained by interviewing Gen-Y buyers was applied on the interior.

"When we interviewed these buyers, they had all of their electronics spread across the whole dashboard on some other competitor products," Ramirez said. "They wanted all their technology to be centralized, and we do that."

Veloster comes standard with a high-resolution 7-in **LG** touch-screen display with Pandora Internet radio capability, **Gracenote** album cover art and voice recognition, video playback via USB, and photo slideshow.

"Every single Veloster will have RCA jacks and a USB, and there's a 115-V outlet, so [**Microsoft**] Xbox or anything with an RCA jack you can play on the video screen," Ramirez said.

The display also incorporates a unique Eco Coach scoring system, which acknowledges fuel-efficient driving with an eco rewards score, and it accumulates points over time for a total Eco Score, which can be compared with other Veloster owners.

The production Veloster is largely reminiscent of that original concept, with a similar profile and rear fascia. The trapezoidal shaped grille of the concept, however, is swapped out in place of Hyundai's traditional hexagon shape. The concept's painted wheel inserts have been carried over as a production option, believed to be a segment first.

The Veloster is slated to go on sale this summer "at a starting price in the $17,000 range," according to Krafcik.

Matthew Monaghan

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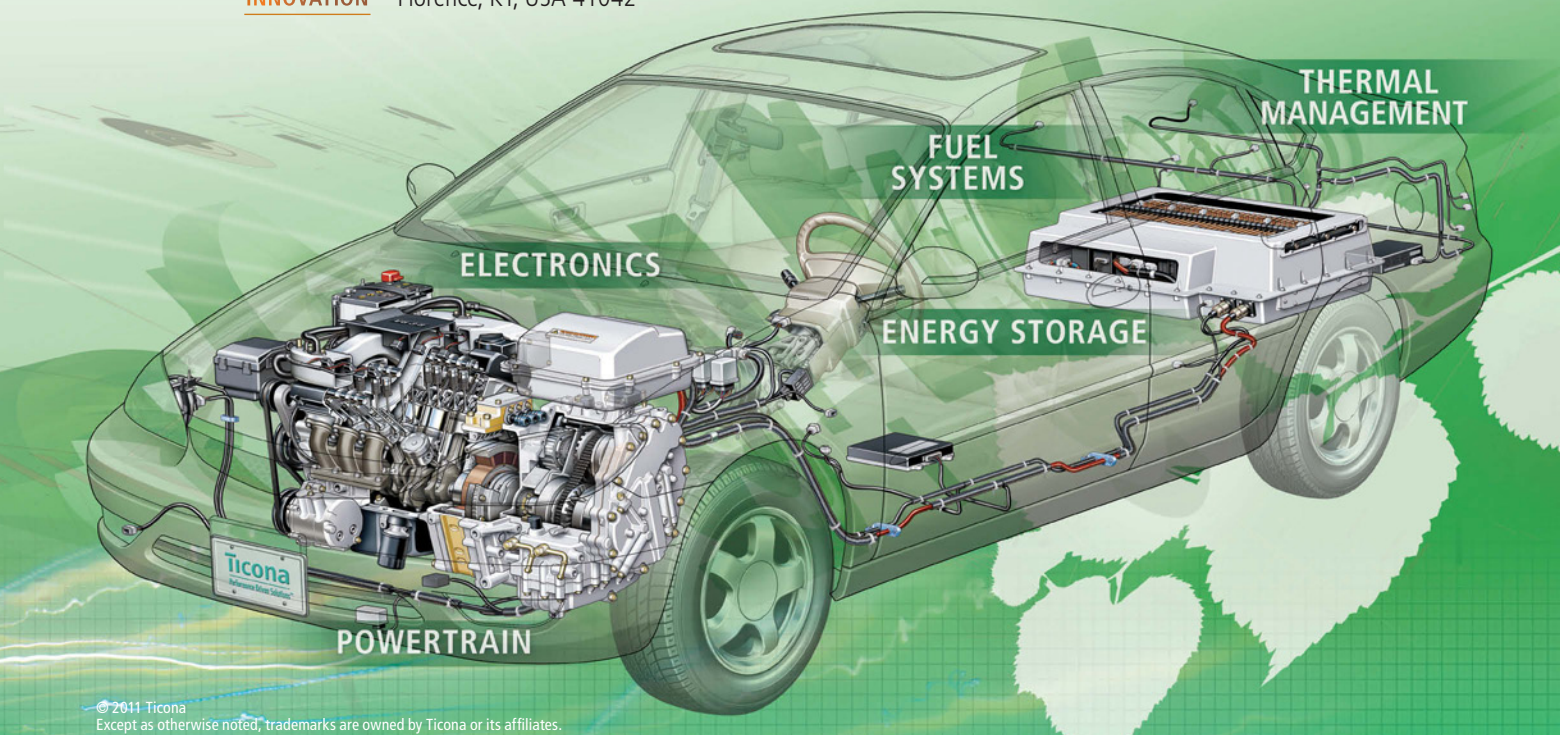
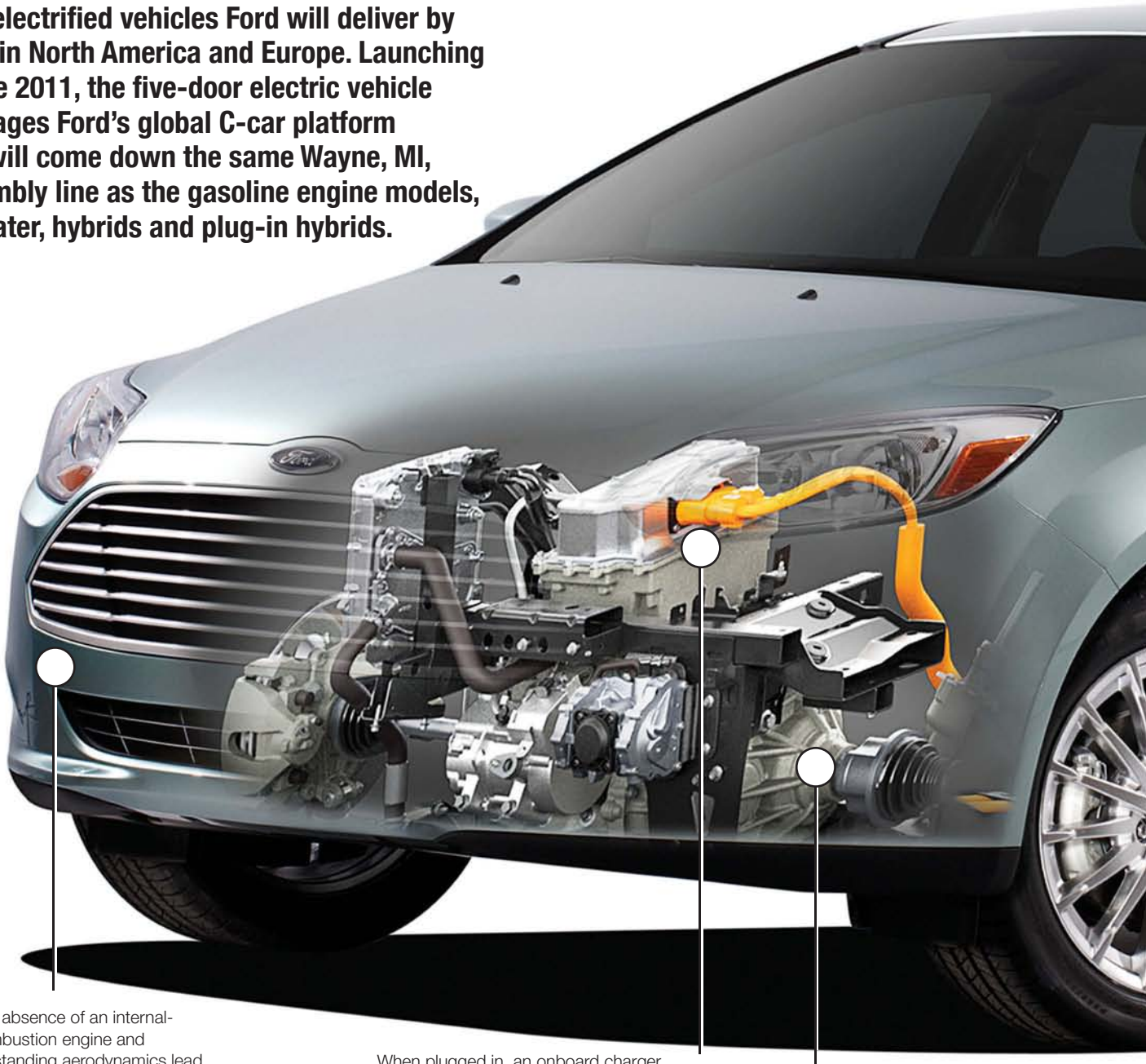


Ford Focus Electric

The 2012 Ford Focus Electric is one of five new electrified vehicles Ford will deliver by 2013 in North America and Europe. Launching in late 2011, the five-door electric vehicle leverages Ford's global C-car platform and will come down the same Wayne, MI, assembly line as the gasoline engine models, and later, hybrids and plug-in hybrids.



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The all-electric powertrain and single-speed transmission provide a top speed of 84 mph (136 km/h). **Magna E-Car Systems** provides the car's 92-kW ac traction motor, single-speed transmission, motor controller, and battery pack, and the supplier helped Ford integrate the electric propulsion system and other subsystems into the vehicle architecture.

Owners get a unique version of the MyFord Touch driver connect system for electric vehicles, a new value charging feature powered by **Microsoft**, and a smartphone app called MyFord Mobile that helps owners control their vehicles remotely. **Mapquest** will enable the smartphone and Focus to receive and display locations of public charging stations.

Ford worked with **Yazaki** to provide an industry-standard five-point plug that is ergonomically comfortable to hold as well as durable. It interfaces with a **Leviton** plug-in battery charger (not shown) that provides double the typical Level 2 rate of charge of other 208-240 V systems, a low installed price of $1500, and **Best Buy** stores' Geek Squad will sell, install, and service.

The 23-kW·h battery pack features cells of the lithium-polymer pouch type from **LG Chem** via its U.S. arm **Compact Power**. A liquid-cooling/heating system covers thermal management.

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Shifting gears smoothly

SAE 2011 President Richard E. Kleine, shown speaking at the 2010 Commercial Vehicle Engineering Congress, joined Cummins in 1981 and now serves as Vice President of its Quality and Business Enterprise/ Mid Range Engine Business.

Kleine, a 30-year veteran of Cummins Inc. and former SAE Commercial Vehicle VP, seeks continuity over change as he moves into SAE's driver's seat.

by Matthew Monaghan

The first year of a U.S. President's term is often viewed as an adjustment period where even mild victories are celebrated. Presidents of **SAE International** do not have that luxury, serving just a one-year term as opposed to the U.S. President's traditional four years. As SAE International works toward its goals of becoming the premier society in the mobility industry according to its Vision 2020 initiative, the transition from one President to the next is crucial as the incoming President must determine his or her own unique focus areas while often carrying on some of the goals of the outgoing President.

"[2010 SAE President Andrew Brown Jr.] and I have spent some time talking about how we transition, not how we change," said 2011 SAE International President Richard E. "Ric" Kleine. "I'm not going to come in and take all his pictures off the wall and put up all my stuff and change it. What I'm going to do is take a lot of what we've started this year and continue it, so we have continuity from one to the other."

Kleine, who serves as Vice President - Quality and Business Enterprise/Mid Range Engine Business at **Cummins** Inc., has had the unique opportunity of working directly with each of the past three Presidents as a member of the SAE Board of Directors, while serving as SAE Commercial Vehicle Vice President.

"Being on the board for the last three years and then moving into the role of President is really a big help because you already know the issues the Board has been facing, what they are looking at for the society, where we're trying to go as a society with our future vision, and you know the personalities involved," Kleine said during a recent visit to SAE World Headquarters near Pittsburgh just prior to the start of his term.

Kleine noted that Brown did an especially good job of keeping the Board engaged throughout the year, something he looks to continue in 2011.

"One of the things that I'll be doing as President is every quarter we're going to meet with the three sector Vice Presidents to discuss what's going on in their sectors with trends, challenges facing the industry, and what are the most urgent needs," Kleine said. "I want to use this forum to increase the sharing of information and perspectives between the sectors and to look for opportunities to address common issues and leverage cross-sector knowledge."

As an example of the benefits of cross-industry sharing, Kleine cited a recent electronics architecture panel at the 2010 Commercial Vehicle Engineering Congress that featured a panelist from the aerospace industry who "brought a lot of insight into that group."

"We need to do more of that," Kleine said. "I want to see, or take advantage and build on, more linkage between the different sectors and better balance."

Shifting gears smoothly

Kleine believes SAE Collegiate Design Series events such as Baja SAE helps students develop organizational skills, giving them good experience for working in industry. He is shown at the 2010 Baja SAE Western Washington event.

SAE International's professional development opportunities, such as classroom and online seminars, can help get young engineers up to speed quickly and help retrain engineers affected by the downturn in the economy, according to Kleine.

Turning on the lights

As Vice President of Quality for Cummins' Mid Range Engine line, which comprises engines ranging from 2.8 to 9 L, Kleine has responsibility for ensuring that the quality of new products being developed meets the quality standards and product validation processes that are rigidly controlled in the Cummins new product release process.

Employed by Cummins since 1981, it was there that Kleine first became involved with SAE. During his early years at the company, he was asked to give a presentation on torsional vibration analysis at a truck and bus meeting. That involvement led to a stint on the Buckendale Lecture Committee and eventual involvement with the Truck and Bus conference organizing committee, and later on the Commercial Vehicle Program Committee and the Commercial Vehicle Congress Executive Committee.

It was a desire to have access to technical information and to be more connected to what was going on in the industry that led Kleine to become involved with SAE. Kleine has seen the value of SAE membership firsthand and during his term as President, he hopes to promote SAE's membership and value proposition to young engineers "because we're not converting as many student members to actual full-time members once they leave academia and go into industry," he said.

As an example, Kleine points to a recent meeting he had with a group of eight engineering students at a university where he serves on the advisory committee.

"I asked the question, 'How many of you belong to professional engineering societies?' And nobody raised their hand," Kleine recalled. "And I asked the committee, made up of senior people from passenger car, weapon systems, aviation, and commercial vehicle companies, 'How many of you are members of societies?' Everybody's hand went up. And you could just see the lights come on for the engineering students as the advisory committee members each discussed what they gained from membership in their professional societies and how it benefited their careers."

Getting up to speed

In addition to providing access to relevant and timely technical information and networking opportunities, Kleine points to some of the indirect benefits that being a member and participating in SAE meetings can provide to younger engineers.

"One of the other things that I think people lose sight of is [membership] gives you the chance to develop and improve skills in being able to organize events, plan and conduct meetings, and other leadership skills that can enhance an engineer's performance in their day jobs," Kleine said. "Some of it you get in college, and that's where you'll see the individuals that come out of Collegiate Design Series already have a lot of those really good skills because they've had to do it, they've had to work under deadlines, they've had to organize, they've had to work through emotional issues with people, and teamwork, and so on. But you get the opportunity to work with teams, you get the opportunity to organize things, you get the opportunity to do presentations and speak, develop your speaking skills. So there's a whole variety of just professional development as well as the technical information that you pick up, as well as the networking that you get across the industry."

Developing young talent should continue to be a focus for SAE International, Kleine believes, as an influx of young engineers is expected to soon join the workforce as many baby boomers enter retirement. Kleine noted that the aerospace industry is

Deere's Vedak takes over as SAE VP–Commercial Vehicle

Bharat Vedak, Vice President, TCI and Deliver Customer Value for Deere & Co., and SAE International's new Vice President of Commercial Vehicle.

Bharat Vedak has been selected as **SAE International**'s 2011-13 Vice President–Commercial Vehicle, filling the void left by 2011 SAE President Richard E. "Ric" Kleine.

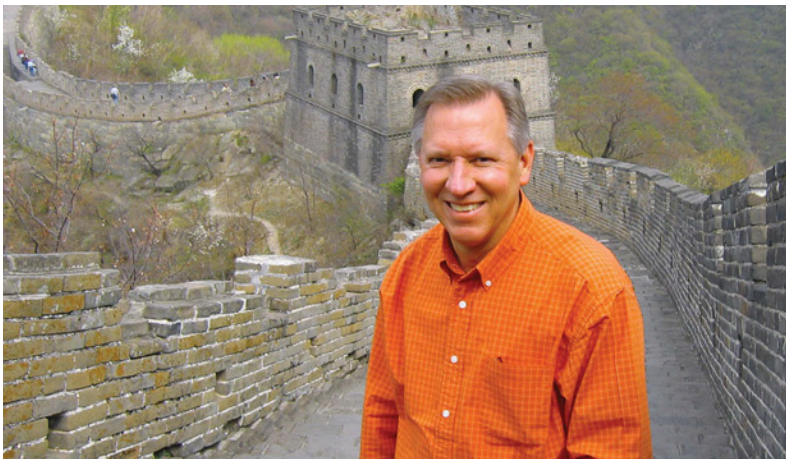
The Vice President–Commercial Vehicle serves a three-year term and is responsible for providing leadership and continuity for SAE International's commercial vehicle initiative and for integrating the needs of automotive vehicles across SAE International's programs for standards, events, and educational programs. SAE International also elects vice presidents for its aerospace and automotive sectors.

Vedak, who is Vice President, TCI and Deliver Customer Value for **Deere** & Co., first joined Deere in 1974 at its Product Engineering Center in Waterloo, IA. In 1983, he became Manager, Quality Engineering at the John Deere Engine Works, and eventually was appointed Vice President of Engineering for John Deere's Rotary Engine Division. In 1990, he joined **Cummins** Inc. as an executive engineer, and advanced to the position of Vice President, Industrial Customer Engineering. He returned to John Deere in 2005 when he was named to the position of Senior Vice President, John Deere Intelligent Mobile Equipment Technologies. In May 2009, Vedak was appointed Senior Vice President, John Deere Intelligent Solutions Group.

Vedak is a Fellow of SAE International, of which he has been an active member for more than 30 years. He previously served as Co-Chair of the 2007 Commercial Vehicle Engineering Congress and 1996 Off-Highway Congress. Vedak serves on the boards of **United Way** of the Quad Cities Area and **XATA** Corp. He has served on the advisory board of the Agricultural and Biological department at **North Carolina State University** and on the Board of Directors of SAE International.

Vedak has a bachelor's degree in agricultural engineering from the **Indian Institute of Technology** in Kharagpur, India, a master's degree in agricultural engineering from North Carolina State University, and an MBA from the **University of Northern Iowa**.

Matthew Monaghan



Kleine is shown visiting the Great Wall during his business travels in 2005.

expected to lose a majority of its experience in the next five years because of retirement, and the commercial vehicle industry is also seeing a growing percentage of its workforce with less than five years' experience, so finding a way to assist with that transfer of knowledge is essential for SAE.

"There's a big need for that now. You've got a lot of young engineers coming out of colleges who are entering the industry with very limited experience. How do we help them understand and come up to speed much quicker?" Kleine asked.

"When you start thinking about getting an engineer involved with doing a design project or doing a controls algorithm, they may not have any idea of the equipment that this thing is going to go in and how it's going to be used. And so the things we take for granted in understanding the mission of a vehicle, aircraft, or piece of equipment and can apply insight in terms of design, flexibility, or optimization, won't exist for a lot of engineers entering industry."

In addition to providing professional development both in person and online, one way of facilitating this transition, Kleine stated, would be to leverage the experience and knowledge of SAE International's longtime members.

"We've got members that have developed a wealth of knowledge during their careers and reach retirement and their day-to-day life changes. There is a lot of knowledge and experience that can be tapped, and we need to develop ways to keep them engaged and provide opportunities that benefit the members and the society," Kleine said.

In addition to training young members, Kleine noted that SAE can also help retrain members that have struggled as a result of the downturn in the economy.

In keeping with the theme of continuity from one SAE President to the next, Kleine echoed Brown's belief that SAE should be the "technology voice of the industry," providing valuable insight on what technologies are most feasible and cost-effective while not representing any single company or group of companies' perspectives.

"We started work in 2010 to identify key industry associations in each sector for the purpose of gaining a better understanding of the challenges and needs of industry," Kleine said. "How do we provide more value to our membership and then how do we get better information from the industry on what are the trends or what's coming up in terms of challenges? How do we get better information flowing into SAE? We need to continually work on ways to increase the SAE International 'value proposition' to its members and to the benefit of society." AEI

Technology expands the Ecotec's reach

Turbocharging, DI, and more boost 2011-12 vehicle applications for GM's do-it-all global four-cylinder.

by **Lindsay Brooke**

The transformation of **General Motors**' North American powertrain portfolio continues at a rapid and in many ways dramatic pace. In 2011 more than 33% of GM's North American engine volume will be four-cylinder engines. Approximately 21% will be turbocharged—seven times more turbo engines than in 2007.

Powertrain analysts at **IHS Automotive** forecast these trendlines to continue. While V6s in the 3.0-4.0-L range are expected to remain core product for the U.S. market in the short to mid-term, GM Powertrain (GMPT) engineers have their eyes on U.S. **EPA** fuel economy regulations for 2016 and beyond, as well as Euro 6, which put significant focus on developing the automaker's global inline-four-cylinder range.

Three families, known internally as Family Zero, Family II, and Family III, carry the Ecotec brand and currently span 1.0-2.4 L displacements (Family Zero also includes 1.0-L triples). Common geometries, components, and manufacturing processes within and across the engine platforms offer GM's vehicle planners "expanded flexibility" in their powertrain choices, noted Tom Stephens, Vice Chairman of Global Product Operations.

In recent years, GM has steadily evolved the DOHC Ecotec fours, adding turbochargers, direct injection, continuously variable valve timing control, twin-port heads, CNG and E85 fuel capability, even Roots-supercharged niche versions. The **Chevrolet** Volt's series-hybrid generator and ongoing development of an HCCI (homogeneous-charge compression-ignition) variant, with two-step valve lift and infinitely variable cam phasing, show there is plenty of headroom left to explore.

In an interview with *AEI*, Stephens predicted, "the Ecotec four-cylinder will be for GM in the 21st century what the small-block V8 was in the 20th—an engine that does it all." This year's vehicle applications appear to prove him out, with turbocharged and naturally aspirated Ecotec fours appearing in 2011-12 **Buick**s and the Chevrolet Cruze Eco.

Buick's broadband four-cylinder

As **Ford** mates its bandwidth-stretching 2.0-L EcoBoost with large vehicles in 2011-12, so does GM begin a similar strategy. For 2011, the 2.4-L direct-injected Ecotec remains as standard in the D-segment FWD LaCrosse (it was added mid-2010). Buick sales executives forecast a bullish 25% take rate for the four-cylinder LaCrosse in 2011.

The non-turbo Family II engine is rated at 182 hp (136 kW) and 172 lb·ft (233 N·m) at 4900 rpm. It's tuned for smooth, low-rpm torque delivery in the 4026-lb (1826-kg) sedan.

Coupled with a Hydra-Matic 6T45 six-speed automatic, the LaCrosse's 2.4-L powertrain delivers an EPA-rated 30 mpg highway/19 mpg city. As a historical comparison, the 30-mpg highway figure is roughly equivalent to that of the 1990s Buick Park Avenue with 3.8-L V6 and four-speed automatic—proving the challenge of increasing fuel efficiency as feature content also rises.

The 2.0-L turbocharged DI Ecotec makes its Buick debut in the 2011 Regal CXL Turbo, a 3600-lb (1633 kg) C/D segment sports sedan based on the **Opel** Insignia. The engine features an air-to-air intercooler and a moderate state of tune; compression ratio is 9.2:1. Pre-production figures as of December quoted 220 hp (164 kW) at 5300 and 258 lb·ft (350 N·m) at 2000.

GM "recommends" premium-octane fuel for its turbocharged Ecotec fours but does not require it. The 2.0-L is mated with an **Aisin** AF40 six-speed automatic.

A higher performance version of the 2.0 L, also with dual VVT and using higher boost pressure and a freer flowing exhaust system, is in validation testing for the 2012 Regal GS due to enter production in the third quarter of 2011. GMPT engineers are aiming for 255 hp (190 kW) and 295 lb·ft (400 N·m) at 2200 to 5200 rpm.

Both turbo DI engines are known within GM by their LHU codes. They are derived from the LNF-coded Ecotecs originally developed to a robust specification for the short-lived Kappa-based sports roadsters but add E85 fuel capability.

Their "Gen II" aluminum cylinder block features stronger bulkheads and high-capacity coolant passages. Bore and stroke are "square" at 86 mm. The crankshaft and connecting rods are forged steel, and the piston crown undersides are cooled by oil jets. The sodium-cooled exhaust valves are in an Inconel alloy.

Maximum boost from the twin-scroll turbocharger is expected to be 20 psi (1.4 bar). The DI fuel system uses a camshaft-driven pump to pressurize fuel at up to 2250 psi (155 bar) at wide-open throttle.

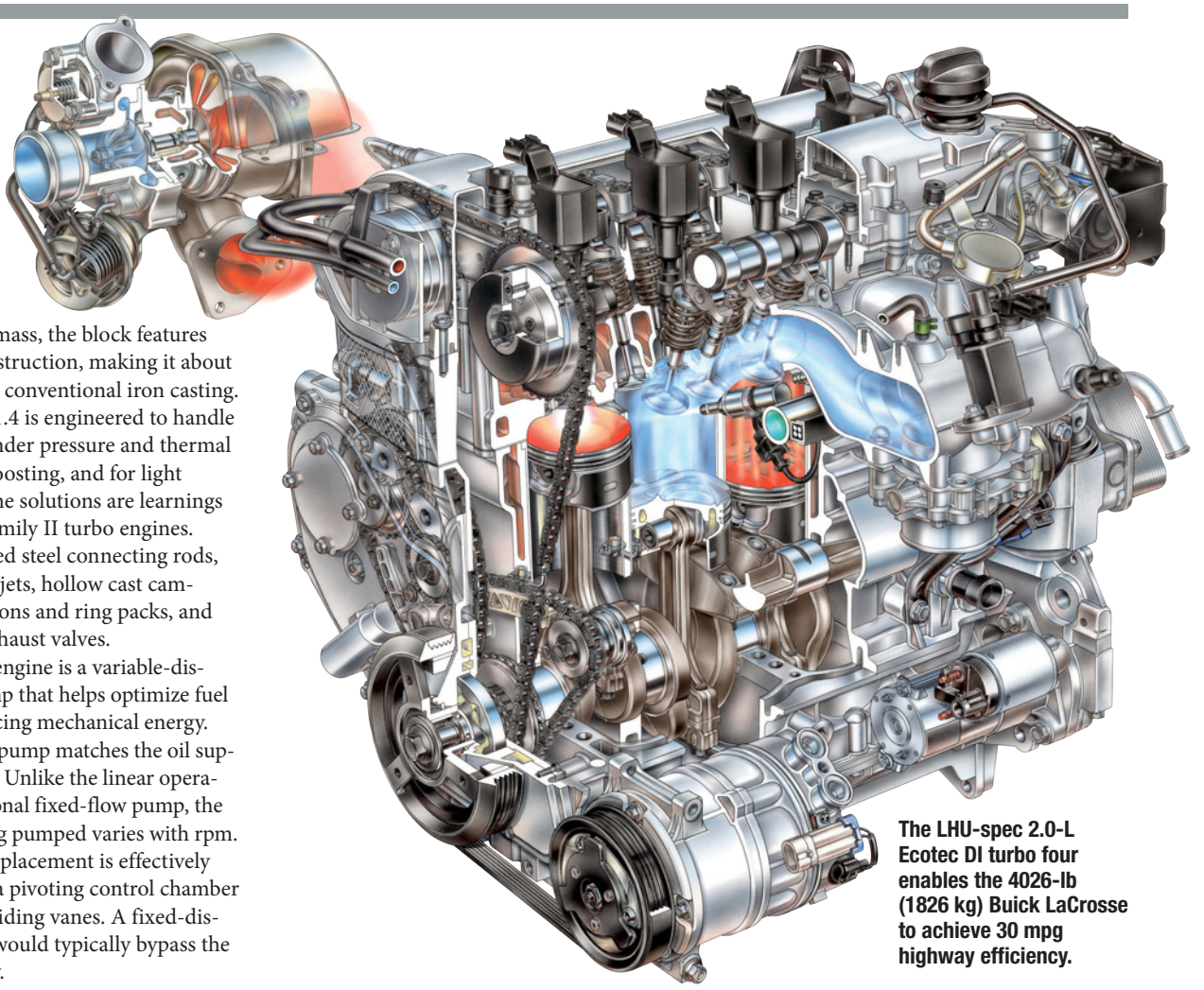
Both 2.0-L turbo engines use a 32-bit ECU that GM engineers are touting as the fastest of its kind in the industry. The E39 controller, which uses **Freescale Semiconductor**'s Qorivva MPC5566 chip, provides 128 MHz clock speed and 3 MB of flash memory.

The 1.4 L's bag full of tricks

GM engineers used various technology solutions to achieve a 42-mpg highway fuel economy rating for the 2011 Chevrolet Cruze Eco, including active aero shutters on the car's grille opening. But the heart of the car's efficiency is its turbocharged 1.4-L Ecotec, which is also standard on the Cruze LT and LTZ models.

The engine's design and calibration are biased toward maximum torque rather than peak power. It delivers 138 hp (103 kW) and 148 lb·ft (200 N·m) between 1850 and 4900 rpm. Unlike the 2.0-L Family II turbo engines, the Family Zero 1.4 L does not employ direct injection, although engineers said the cylinder head is design-protected for DI. Compression ratio is a modest 9.5:1. The 1.4 L turbo for North American use is calibrated for 87 octane gasoline.

Also different is the cylinder block, a gray-iron casting rather than aluminum. The block does not incorporate balance shafts due to the smaller displacement; its gray-iron bedplate helps minimize the effects of vibration in conjunction with a cast-aluminum structural oil



The LHU-spec 2.0-L Ecotec DI turbo four enables the 4026-lb (1826 kg) Buick LaCrosse to achieve 30 mpg highway efficiency.

pan. To optimize mass, the block features hollow-frame construction, making it about 20% lighter than a conventional iron casting.

Internally the 1.4 is engineered to handle the increased cylinder pressure and thermal loads caused by boosting, and for light weight. Many of the solutions are learnings from the larger Family II turbo engines. They include forged steel connecting rods, piston oil-cooling jets, hollow cast camshafts, unique pistons and ring packs, and sodium-cooled exhaust valves.

Unique to the engine is a variable-displacement oil pump that helps optimize fuel efficiency by reducing mechanical energy. The crank-driven pump matches the oil supply to engine load. Unlike the linear operation of a conventional fixed-flow pump, the volume of oil being pumped varies with rpm.

The pump's displacement is effectively changed through a pivoting control chamber mechanism and sliding vanes. A fixed-displacement pump would typically bypass the extra oil internally.

"By lowering the volume of oil, we reduce the amount of energy, or torque, required to pump the oil, without taking necessary lubrication away from the engine," noted Mike Katerberg, Assistant Chief Engineer for the 1.4 L. "Reducing the torque demand reduces fuel consumption."

GM designed the pump for the 1.4 L for use with the engine's twin hydraulically actuated camshaft phasers. He explained that the pump design was adopted from the variable-displacement oil pumps used in GM automatic transmissions and in its hybrid powertrains.

An oil-to-water heat exchanger is incorporated into the oil filter housing. It enables faster heating of the engine oil during cold starts, reducing internal friction earlier.

Low-down torque from Honeywell turbo

GMPT engineers worked with their counterparts at **Honeywell Turbo Technologies** to develop Honeywell's MGT14 turbo for use on the 1.4. Much analysis and CFD work were done to size the turbo's frame and compressor wheel to optimize low-speed torque and rapid throttle response, without lag.

The Honeywell turbo is integrated with the cast exhaust manifold to speed catalyst light-off via a close-coupled catalytic converter. Honeywell engineers also worked with GM to develop the Cruze's air-to-air intercooling system.

Katerberg explained how the turbocharger broadens the 1.4 L's speed range for peak BMEP (brake mean-effective pressure). "The turbo gives a flat torque curve from around 2000 to almost 5000 rpm. A normally aspirated engine typically has a torque peak in the 3000 to 4000-rpm range. An internal comparison was made with a 1.8 L engine making the same 103 kW peak power.

"The 1.4 L had a 32% torque advantage in the low-rpm range (approximately 2000 RPM) and a 14% advantage in the mid-rpm band [approximately 3500-4000 rpm]," he said.

The torque advantage of the downsized, boosted engine allowed Katerberg's and the vehicle-development teams to optimize transmission gear and final drive ratios for the desired balance between fuel economy and performance in the Cruze.

Katerberg said the outcome was 42 mpg in highway fuel economy with the Cruze Eco and six-speed manual gearbox with outstanding driveability. "The flat torque curve also provides less shift-busyness with the automatic transmission," he noted.

The Cruze's standard engine is the 1.8 L Ecotec. Although naturally aspirated, it uses a gray-iron block that is similar in design to that of the 1.4-L turbo. The 1.8-L engine is port-injected and incorporates the turbo engines' piston-oil-cooling jets, oil cooler, hollow camshafts, twin VVT phasers, among other technologies, for greater durability and efficiency.

A composite two-stage variable intake manifold also helps increase fuel economy and performance. At engine speeds below 4000 rpm, inlet air passes through 35.8-in-long (910 mm) intake tracts that help boost torque. At speeds above 4000 rpm, an internal rotary sleeve closes off the full length of the intake tracts, forcing air through a 10.2-in (260 mm) tract that helps build horsepower.

The induction system enables the Ecotec 1.8 L to produce approximately 90% of peak torque from 2400 to 6500 rpm. Claimed output is 136 hp (101 kW) and 123 lb·ft (167 N·m) at 3800 rpm. AEI

EcoBoost offensive shifts to four cylinders

Ford deploys its DI + turbo + Ti-VCT punch to two high-volume I4 families.

by **Lindsay Brooke**

Is this the year small-displacement gasoline engines begin to strike back? Certainly in 2011 boosted, direct-injected, spark-ignited engines will start ramping up toward significant production volumes across the industry. They will attempt to lure Americans away from their V6s and challenge diesel's dominance in the critical B and C segments in Europe.

The growth is particularly aggressive at **Ford**, which was among the first global OEMs to make downsized-and-turbocharged petrol engines a keystone of their CO_2-reduction strategies. For MY2011, the company is expanding its so-called EcoBoost technology into the Sigma-based 1.6-L and Large I4-based 2.0-L. Sigma and the Large I4 are two of Ford's highest-volume four-cylinder architectures.

Both applications feature the triad of high-pressure DI, low-inertia turbochargers, and twin independent variable camshaft phasing (Ti-VCT).

Ford's march toward a predominantly EcoBoost future is one leg of its powertrain efficiency strategy that also includes increasing vehicle electrification. By 2013, 90% of the company's North American vehicle portfolio will be available with EcoBoost engines, noted Group Vice President of Global Product Development Derrick Kuzak. He expects four-cylinder engines will constitute two-thirds of the EcoBoost lineup before mid-decade.

For the 1.6-L EcoBoost engine (and its 1.5-L sibling), global production volumes are expected to leap from more than 90,000 engines in CY2011 to nearly 470,000 in CY2014, according to Jeff Jowett, a Powertrain Analyst at **IHS Automotive**.

Pushing the 2.0-L bandwidth

The 2.0-L, manufactured in Valencia, Spain, is Ford's first global EcoBoost engine. It debuted in MY2010 in the European Galaxy, Mondeo, and S-Max and will also see early duty in the 2011 Falcon (Australia). A high-output variant will power the 2012 Focus ST (see Dec. 7, 2010, print edition, p.30).

But the real test of the boosted 2.0-L's bandwidth will be in two larger, heavier North American market products: the 2011 Edge and 2012 Explorer. Their hefty base curb weights (4082 lb/1852 kg for Edge, 4355 lb/1975 kg for Explorer) traditionally would have required V6 muscle.

"We walk a fine line between how far we can downsize and boost the engine, depending on the vehicle application," noted Scott Makowski, Manager of Global Large I4 Programs. "But in applications when you're not at peak power all the time, a nicely matched turbocharger with Ti-VCT reduce pumping work and frictional losses compared with a big naturally aspirated engine."

Extensive modeling showed Makowski's development team that 2.0 L of displacement, plus turbocharger, would provide more than sufficient thrust in Edge and Explorer. Swapping the 3.5/3.7-L V6 for the boosted inline four also saves 55 lb (25 kg) in overall vehicle mass.

Makowski explained that despite the typical bore/stroke trade-offs when developing a boosted engine, the DI/turbo package turned out to be "highly effective" with the Large I4 engine family that currently ranges from 1.8 to 2.5 L. The 2.0-L's oversquare 87.4 x 83.1 mm bore/stroke dimensions give a 1.05 ratio that he said works splendidly with the induction system, he said.

The high 12:1 compression ratio enabled by DI is mitigated by Ford's Adaptive Knock Control (AKC), a closed-loop ignition timing system proven on the naturally aspirated Duratecs.

AKC enabled Makowski's team to more precisely advance spark to the threshold of detonation across all operating and ambient conditions. This helps fuel efficiency and reduces engine-out NOx. The system also constantly adjusts for increased combustion-chamber deposits over time, he added.

Compared with its naturally aspirated cousins, the 2.0-L EcoBoost has approximately 15% higher firing pressures. This required the team to upgrade the reciprocating hardware, using solutions similar to those used on the 1.6-L EcoBoost.

The crankshaft remained nodular cast-iron rather than steel but gained a higher strength material. It spins in an aluminum cylinder block that is structurally improved and features "inner-bore cooling"—coolant passages located between the bores just below the deck face to handle the turbo engine's greater thermal loads. The lightweight full-floating pistons are a stronger casting and feature low-friction coated skirts. They ride on forged steel connecting rods with precision-fractured "cracked" big ends.

Along with the newly added twin phasers and their oil-control solenoids for the intake and exhaust cams, the 2.0-L's cylinder head is upgraded with high-temperature sodium-filled exhaust valves and hardened seats. The tappets' friction surfaces are micro-polished, a benefit proven on the 3.7-L EcoBoost V6. The four-cylinder engine also gets high-energy ignition coils.

The DI system used on the standard 2.0-L EcoBoost for Edge and Explorer features **Denso** six-hole solenoid-actuated injectors, operating at up to 2150 psi (148 bar). A key difference between the 2.0- and 1.6-L turbo engines is their fuel injector locations—on the side of the combustion chamber on the 2.0 L and in the center of the chamber next to the vertical spark plug on the 1.6 L.

Without specifying minimum octane ratings, Ford engineers said the engines are calibrated for "regular" fuel and are E85 compatible. The injection system in the

The 1.6-L EcoBoost is based on Ford's Sigma family architecture. The twin independent cam phasers each operate in conjunction with one oil-control solenoid per camshaft. Note cast exhaust manifold, structural oil pan, BorgWarner low-inertia KP39 turbocharger.

high-performance (247 hp/184 kW) Focus ST version operates at up to 2200 psi (152 bar) and uses seven-hole injectors. When this story was published, Ford had not yet released the ST engine's fuel octane requirement.

Makowski said his team considered every available type of boosting system, including supercharging and even turbo-supercharging (as currently used by **Volkswagen**) for the program.

"Our analysis of boosting technologies was very comprehensive," he explained. "But we concluded that turbocharging with DI offers the best solution for fuel economy with downsized engines. The technology must work in the mainstream and be affordable to the masses; that's more of a challenge with some of the turbo-supercharger solutions. And at the end of the day there are a lot less parasitics with turbos."

Sizing up turbochargers

Ensuring that the 2.0 L delivers strong torque across the rev range, particularly for larger vehicles, meant "a lot of soul searching and analysis" in sizing the turbocharger frame and compressor, Makowski noted. "We wanted all the attributes, of course, but at the end of the day the engine had to deliver that low-end torque. Also we couldn't live with turbo lag."

Ford engineers worked with their counterparts at **BorgWarner**, which supplies the turbochargers for both the 2.0 and 1.6 L. Makowski described the model K03 turbo used on the 2.0 L and KP39 used on the 1.6 L, as "moderately sized" for their applications.

"We could get more peak power by going with a larger turbo, but the low-rpm range would really struggle to meet the customer expectation of power available immediately when you hit the gas," he said. "The turbos we use are light and their smaller frame size [compressor size] and low-inertia turbines are sized to make that compromise between peak horsepower and peak torque."

The turbo systems incorporate active wastegate control and use air-to-air intercoolers. Turbocharger "whoosh" is attenuated by electronically controlled anti-surge valves that proactively relieve the boost in the intake, according to Olaf Kunde, Ford's Powertrain Systems Manager. Intake boost pressure can range up to 13 psi (0.9 bar) on the standard 2.0-L EcoBoost engines, up to 16 psi (1.1 bar) on the ST, and up to 17 psi (1.17 bar) on the 1.6 L.

Makowski said the team achieved its performance bogey of no turbo lag and broad-torque delivery. Maximum torque is maintained from slightly less than 2000 to 5500 rpm. By comparison, the 1.6-L maintains its peak torque from 1500 to 4500 rpm.

AEI's brief drive of a pre-production Edge in mid-November 2010 confirmed throttle tip-in and acceleration to 50 mph (80 km/h) to be equivalent in feel to that of the base 280-hp (209-kW) 3.5-L V6. The EcoBoost engine option in Edge and Explorer will carry a nearly $1000 price tag.

The K03 turbo configured with stainless steel exhaust manifolds and a Mar-M-246 material turbine wheel is capable of running 1050°C exhaust temperatures, according to Tom Grissom, BorgWarner Turbo Systems' Director of Business Development. The KP39 used on the 1.6-L EcoBoost also will be capable of 1050°C.

Grissom told *AEI* that the 2.0-L EcoBoost engine will have both standard (970°C) and high (1050°C) exhaust gas temperature ratings, depending on vehicle application. Differences in U.S. and European emissions standards will require different exhaust manifolds for the two markets, Grissom noted.

Ford engineers also optimized engine efficiency by reducing parasitics through the engines' accessory drive system. Besides the electric power-assisted steering (EPAS), an alternator decoupler (essentially a special pulley that reduces certain types of vibrations) allows the alternator and water pump drive belt to operate at lower tension levels than typically used. And so-called "stretchy belt" technology enabled the A/C compressor belt tensioner to be removed.

Ford engineers expect the 2.0-L EcoBoost Edge to exceed 30 mpg in its EPA highway rating. They are confident overall fuel efficiency will improve up to 20% over the 3.5-L V6's 19 city/26 highway rating.

Details on the 2.0-L Explorer are expected this spring. Due to its small engine/large vehicle marriage, it is one of the most anticipated new vehicles in engineering circles. **AEI**

2011 Pentastar is Chrysler's new do-it-all V6

It replaces seven engines, resulting in considerable cost savings and manufacturing complexity.

by **Paul Weissler**

Turning **Chrysler** into a cost-effective manufacturer that can produce competitive vehicles is a job that is being attacked on many fronts. One of the most important engineering steps toward that goal is the recent introduction of the 3.6-L Pentastar V6.

Why can one new engine make a big difference? After all, almost every other automaker has a DOHC V6 in the 3.5 to 4.0-L displacement class, and in many cases it has enabled a phase out of a pair of older engines. At Chrysler, however, the new V6 is putting seven incumbent V6 engines (six in domestic use) into retirement. The considerable savings from reduced bill of materials and manufacturing complexity is a key part of the strategy, of course.

Instead of 189 major components for seven "legacy" V6s being discontinued, Chrysler now needs just 32 for all current variants of the 3.6-L V6. A major contribution is made by eliminating separate exhaust manifolds—they're integrated with the Pentastar cylinder heads. Formerly 32 exhaust manifolds had been required for the seven obsoleted engines.

Likewise, just two intake manifolds (each with upper and lower sections) are specified for the new Pentastar V6—four total parts, not including fasteners, for Pentastar vs. 32 parts for its seven predecessors.

Even as Chrysler adds Pentastar variants, including versions with smaller cylinder displacement and engineering features needed to meet tightening fuel economy standards, the total bill of materials for the Pentastar family is expected to remain a fraction of the 2010 number for the seven retirees.

The single-V6 strategy offers many other benefits, including the promise of higher quality, the ability to upgrade for new vehicle applications more efficiently, reduced service complexity, and lower warranty expense.

The Pentastar engine program began during **Daimler**'s ownership of Chrysler. The program went on hiatus when **Cerberus Capital Management** became Chrysler's next owner and began looking at alternatives. The V6 effort appeared to sputter, as Chrysler's engineering manpower was stretched ever thinner under Cerberus and the economic recession. But development was ultimately restarted, finished, and the engine brought into production during 2010 by the Chrysler engineering team.

Besides replacing the patch quilt of obviously dated V6s in the company's engine portfolio, Pentastar was designed with the highest possible level of flexibility for much of the Chrysler product lineup—present and future. It will likely see some applications for new parent **Fiat** as well.

Technical features

The DOHC aluminum engine will be initially made in four closely related variants. One develops a claimed 283 hp (211 kW) for transverse front-drive applications. The rear-drive version produces a claimed 290 hp (216 kW), and the one developed for all-wheel-drive use is rated at 292 hp (218 kW).

A fourth, high-performance variant offers the magic "over 300" number – 305 hp (227 kw) to be specific, for use in the rear-drive **Dodge** Challenger. That horsepower rating is **SAE**-certified on regular 87-octane gasoline. It also is capable of running on E85.

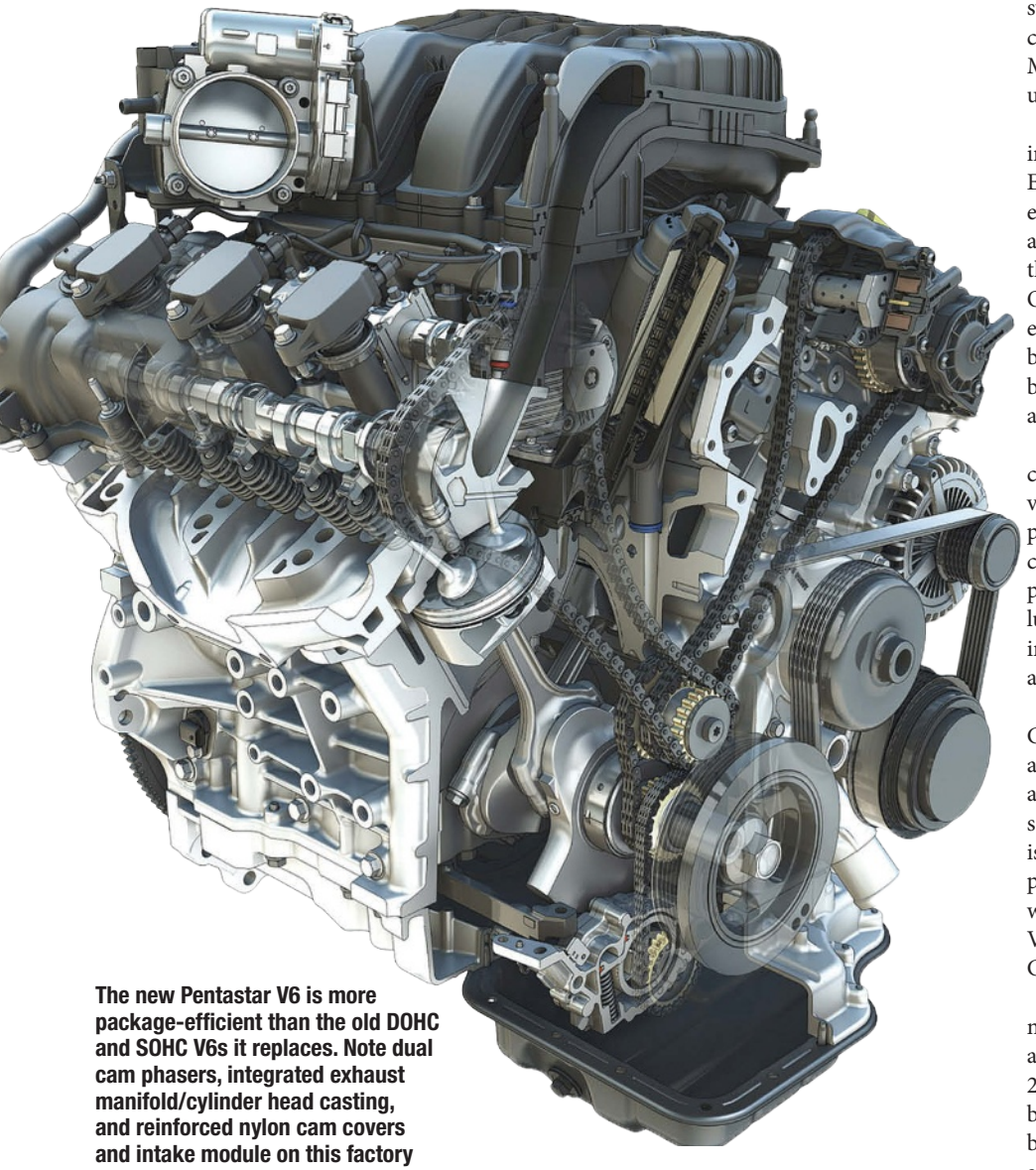
The cylinder blocks configured for transverse and longitudinal applications are architecturally similar. Each incorporates a structural windage tray and oil-cooling jets aimed at the undersides of the piston crowns. There are just two cylinder heads covering all variants. Engine internals are exactly the same, including the camshafts and pistons.

The valvetrain features camshaft phasing on intake and exhaust. Rolling-element valve lifters help reduce friction.

The Pentastar V6s are shorter in height than the various overhead-cam engines they replace. This improves powertrain package efficiency and helps expand the Pentastar's potential applications within the future Chrysler and Fiat vehicle portfolios.

Much design-engineering focus went into routing the intake and exhaust systems to optimize output. (Because the present variants are internally the same, horsepower differences between north/south and transverse applications are strictly due to routing and shape of intake and exhaust systems, and software calibrations.) In the case of the Challenger, a more aggressively designed intake air system is the enabler for the 13-hp (9.7-kW) increase vs. the other longitudinal fitments, allowing an airflow increase from 214 to 220 g/s.

Bore and stroke of the 3.6-L Pentastar V6 measure 96 x 83 mm, and Chrysler engineers are working on other displacements for the future, including a reported 3.0-L turbocharged version. The Pentastar architecture was protected for the future addition of other technologies Chrysler engineers and product planners deem necessary to keep the engine competitive. The



The new Pentastar V6 is more package-efficient than the old DOHC and SOHC V6s it replaces. Note dual cam phasers, integrated exhaust manifold/cylinder head casting, and reinforced nylon cam covers and intake module on this factory cutaway.

systems include direct fuel injection and cylinder deactivation (Chrysler's MDS, or Multiple Displacement System as currently used on the 5.7-L Hemi V8).

Fiat's Multi-Air system also is being investigated for use on the Pentastar family. Extensively reported in *AEI*, Multi-Air uses electrohydraulic actuators to vary valve lift and timing and deliver intake valve throttling (instead of using a throttle plate). One operating stage of Multi-Air effectively equals cylinder deactivation. Multi-Air can be incorporated into gasoline engines with both direct injection and turbocharging and also can be used on diesels.

A variable-displacement oil pump with a computer-actuated flow-pressure control valve is one key contributor to Pentastar's projected improvement in fuel efficiency, compared with the outgoing V6s. The pump's displacement is reduced when the lubricating oil is cold and thick and increased when it is hot and thin. Pressure and flow are reduced below 3500 rpm.

The new V6 is built on a new line at Chrysler's Trenton, MI, plant. Some of the advanced technologies (and new vehicle applications) are coming in 2012, when a second plant under construction in Mexico is due to come on stream. The two production lines will be virtual twins, each with a capacity of about 440,000 engines. Volume is expected to ramp up sharply in CY2012.

The introduction of Fiat Group vehicles may add a new look to the Chrysler lineup, as well as a new mix of powertrains. The 2011 Chrysler and Dodge sedans with the base 2.4-L four-cylinder "world engine" have been refreshed, and for options they will take some of the Pentastar production. But for the vehicles Chrysler sells in volume—Jeeps, minivans, and soon pickups as well—the new V6 is expected to be the prime mover. AEI

Pentastar puts seven 'legacy' V6s into retirement

With the introduction of the new 3.5-L Pentastar V6 for 2011, **Chrysler** will relegate the following engines to the history books:

- 3.3/3.8 L OHV: These 60° engines, with cast-iron blocks, have powered everything from minivans to **Jeep**s. The 3.3 L has been in production since 1990; the bored-and-stroked 3.8-L version came in 1991. A 2.97-L (nominally 3.0-L) version was briefly built for the Chinese market in 2008.
- 3.5 L SOHC: This 60° aluminum engine, originally developed for the 1993 LH front-drive sedans, was used most recently in Chrysler/Dodge FWD sedans.
- 2.7 L DOHC: Introduced in 1998, this 60° engine's unique design features (DOHC heads; specific bore spacing; timing chain instead of a belt; active intake manifold) required a dedicated assembly plant.
- 4.0 L SOHC: The stroked version of the SOHC 3.5-L was introduced in MY2007 to provide more torque, particularly for minivans and the Pacifica crossover.
- 3.7 L SOHC: This 90° V6 was co-developed with the 4.7-L V8 and introduced three years after it.

Not only are all the performance levels of the "legacy" engines well below the starting point for the Pentastar, but their fuel economy is about 7% lower overall. When the Pentastar variants reach anticipated volume in the 2016-18 time frame, Chrysler expects them to add 2 mpg to the U.S. CAFE gap that has to be filled.

Until Pentastar volume is fully ramped up (expected by summer), the 3.8-L V6 will remain in the Jeep Wrangler, and the 3.7 L will continue in the Dodge Nitro and Jeep Liberty.

Paul Weissler

Mazda readies Skyactiv engines

The gasoline and diesel units share the same 14:1 CR and manufacturing processes.

by **Jack Yamaguchi**

Mazda has pulled the cover off its next-generation engine strategy, called "Skyactiv." Slated to enter production in 2012, Skyactiv includes all-new spark- and compression-ignition engines that share various design attributes and combustion techniques (including a 14:1 compression ratio). They will also share some machining and assembly processes.

The new engines, known as Skyactiv-G (gasoline) and Skyactiv-D (diesel), are claimed to deliver significantly greater fuel efficiency and lower emissions than Mazda's current lineup.

Initial vehicle applications for the gasoline versions are expected to include Mazda's all-new C/D-segment platform (the current one underpins Mazda6 and derivative CUVs), powered by a 2.0-L inline four-cylinder, and the B-segment Demio (Mazda2), powered by a 1.3-L four. The first diesel version shown publicly is a 2.2-L prototype fitted to a Mazda6.

Most importantly, the Skyactiv program reveals Mazda engineers' focus on merging gasoline and diesel technologies. "My ultimate goal is the Ideal ICE," explained Mitsuo Hitomi, head of Mazda's Powertrain Development Division and a chief architect of Skyactiv.

He said the program's path toward creating the ideal internal-combustion engine (ICE) involves optimizing six "control factors"—compression ratio, air-to-fuel ratio, combustion period, combustion timing, pumping loss, and mechanical loss. All six factors currently are close to ideal in the diesel, he said, and all but one (air-to-fuel ratio) are close to ideal in the gasoline engine. For that, Hitomi is aiming at lean-burn combustion.

The new gasoline engines feature direct fuel injection (DI) and are naturally aspirated. Hitomi is a turbocharger and supercharger expert, but he has not jumped on the downsized-and-boosted bandwagon. He strongly believes significant efficiency improvements are still to be found without resorting to boosting's complexity and cost.

The results to date appear to prove him out. In prototype testing, the 2.0-L Skyactiv-G produces approximately 15% better fuel economy than the company's incumbent MZR 2.0-L engine, or equal to a comparable-size diesel. Low- and mid-range torque is improved by about 15%. For the Skyactiv-D, claimed fuel ecomomy is increased by about 20% vs. Mazda's current diesel.

The new diesel will be compliant to EU Stage 6, U.S. Tier 2 Bin 5, and Japan's stringent Post New Long-Term Emission Standards without requiring selective catalytic reduction (SCR) and lean NOx traps (LNT), according to the company.

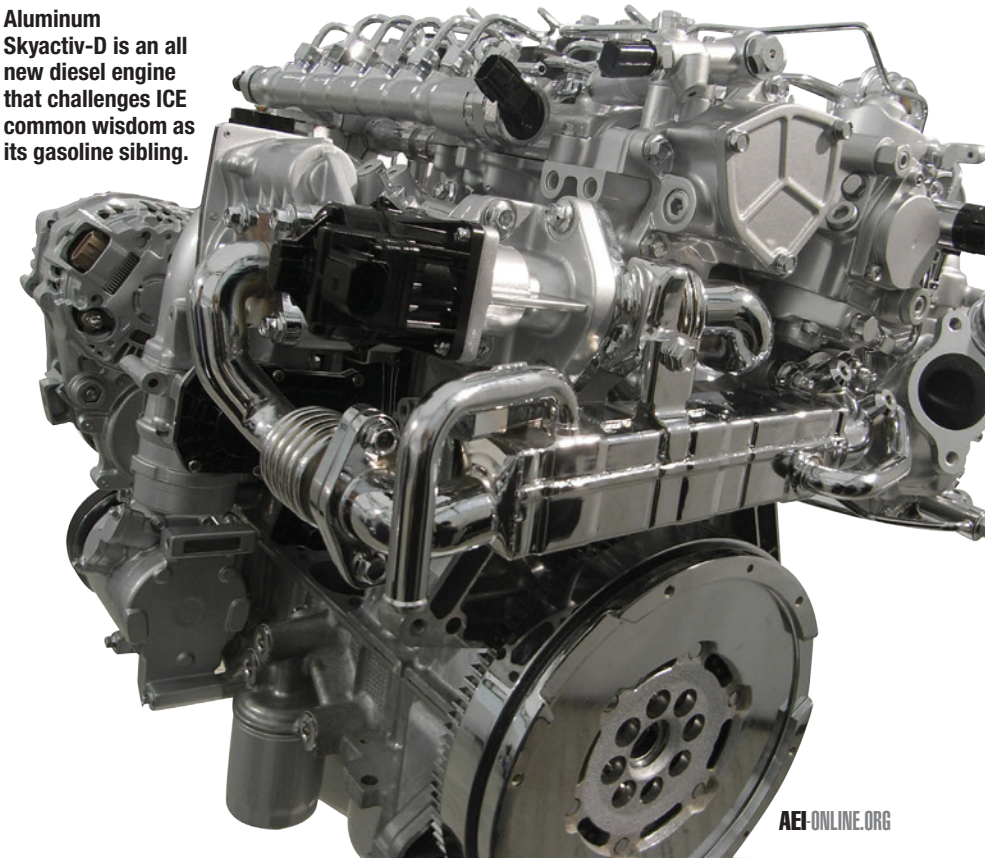
Inside the Skyactiv-G

In developing the 2.0-L petrol engine, Hitomi's team designed a more compact combustion chamber compared with the MZR's, to reduce cooling loss due to surface area. The target surface-to-volume ratio required the new Skyactiv-G to be a long-stroke engine. While the port-injected MZR is oversquare, with an 87.5-mm cylinder bore, the new DI engine's bore measures 83.5 mm. *AEI* surmises a 93.2-mm stroke; Mazda has not yet revealed the actual stroke figure.

Raising compression ratio in a spark-ignition engine measurably improves thermal efficiency and torque. Along with DI, one of the features that enables the Skyactiv-G's high 14:1 compression ratio is its long, intricately shaped 4-into-2-into-1 exhaust system. The unique system is designed to minimize exhaust blow-back into the inhaling cylinder.

Reducing the percentage of residual exhaust gas from 8 to 4% enabled engineers to raise the compression ratio by a factor of three on the Skyactiv-G prototype, while maintaining the same temperature level at TDC during the compression stroke as on an 11:1 baseline engine equipped with conventional 4-into-1 exhaust.

Hitomi acknowledged the new exhaust system is more expensive than a conventional one. Its complex upper 4-into-2 section of equal-length tracts is stamped and fabricated. The sys-



Aluminum Skyactiv-D is an all new diesel engine that challenges ICE common wisdom as its gasoline sibling.

tem is loop-shaped to reduce its installation length but still requires a unique vehicle underbody to package it, as evidenced by a Mazda6 mule fitted with the prototype engine. (The Demio/Mazda2 platform has no room to accommodate the 4-2-1 exhaust system; Hitomi's team will have to find another solution to compensate.)

"The length of the system, 600 mm to the integrated catalyst entry, cools down exhaust by 60° to 70°C when the engine is warmed up," Hitomi explained. "It can be a drop of 200°C on cold start-up." The team addressed the extreme temperature drop using combustion techniques, rather than by resorting to costly add-ons such as secondary air injection.

To fully exploit the super-high compression ratio, the Skyactiv-G's piston crown incorporates a small bowl-shaped cavity that ensures fast and smooth flame propagation.

Hitomi explained, "Quick catalyst lightoff is achieved by delayed ignition; however, combustion must be stabilized in this adverse condition. It is achieved by charge stratification, forming rich mixture around the spark plug utilizing the 'hill' around the piston cavity, while maintaining total air-to-fuel ratio remaining stoichiometic. Stable combustion is realized as the piston makes downward stroke," he said.

During low-load operations, including idling, the Skyactiv-G runs an extreme Miller (Atkinson) cycle. Using late intake-valve closing enables operation at higher compression/expansion ratios without detonation. The engine is equipped with electrically actuated variable valve timing (EVVT) and camshaft phasing on both intake and exhaust. The dual-EVVT facilitates higher phasing velocities and accuracy with greater control flexibility over the engine's speed range, compared with hydraulic-type VVT systems.

"Fast is the key element," said Hitomi. "It must phase valve timing fast and precisely when load is increased, otherwise the engine's responsiveness, equal torque generation, would have been seriously delayed."

He added that without the super-fast EVVT, in cold ambient temperatures the engine's extremely late intake valve closing could starve the engine of air. Cars with automatic transmissions thus might not produce enough power to drive the torque converter.

During the Skyactiv-G's low-load Miller-cycle operation, it runs on a lower effective compression ratio, reducing pumping loss. However, switching to the high compression ratio during high-load operation via the EVVT requires extremely precise control strategy and action—no mean task, Hitomi noted.

Pushing the new gasoline engine to the practical boundary of high compression ratio enabled Hitomi's engineering team to take advantage of low-temperature oxidation, an exothermic reaction that unlocks some extra chemical energy in the fuel. To exploit the reaction, the Skyactiv-G's ignition timings for mid- and high-load operations are set after TDC.

The **Denso** fuel injector is a solenoid-driven multihole type. Basically the strategy is single injection during the intake stroke; however, during low-speed, wide-open conditions, another injection is added during the compression stroke. Multiple injections may be employed under special conditions such as cold operation, according to Hitomi.

There is no variable device in the intake manifold system. Tumble motion of the incoming air is promoted by curved and 450-mm-long (17.7-in) quad-tracts.

Hitomi said the new engine is perfectly happy with its 14:1 compression ratio and under-13-bar (188-psi) BMEP. The prototype runs on premium 95-RON fuel, aided by a knock-sensor installed in the cylinder block. The ignition coils atop each spark plug are equipped with an ion sensor that may be fed with an additional spark under certain conditions to improve sensing accuracy.

Numerous measures are taken to reduce frictional losses and mass in the Skyactiv's reciprocating components, including roller cam followers, smaller-diameter and narrower crankshaft journals, and lighter pistons, wrist pins, and connecting rods. An electronic variable-pressure oil pump reduces lubricant pumping loss by about 45%. Hitomi said there are no exotic or racing-grade materials used in the engine.

Cam-switching for the low-compression diesel

The Skyactiv-D diesel, also scheduled for 2012 production, is an all-new aluminum DOHC inline four with four valves per cylinder. It employs the latest Denso piezo-type fuel injectors and a two-stage turbocharger, among other innovative features and control strategy. The 2.2-L prototype, comparable to Mazda's current CDI unit in displacement, has shown 20% fuel economy improvement and higher torque across the rpm range that extends to 5200 rpm.

Because of its low (for a diesel) 14:1 compression ratio, the compression temperature and pressure decrease at TDC. Consequently even when fuel is injected at TDC, it takes a longer period of time to ignite. This allows uniform mixture formation without localized high-temperature areas and oxygen-scarce spots (the causes of NOx and soot emissions), according to Mazda engineers.

Auto ignition still occurs sooner than on conventional (16:1-18:1) diesels. Fuel is injected near TDC rather than the conventional late injection during the downward stroke.

Hitomi noted two challenges in establishing the low compression ratio: engine starting and stable combustion during warm-up. The engineers solved the first with an elaborate and precise fuel injection strategy. The basic injection sequence comprises pre-injection, main-injection, and post-injection. However, the system may employ as many as nine injections per combustion cycle, depending on requirements.

The Skyactiv-D is equipped with a cam-switching system on the exhaust side, "not unlike [**Honda**'s] VTEC," observed Hitomi. The system acts on one of the two exhaust valves in each cylinder. After engine start and a single crankshaft revolution that sufficiently heats exhaust gas, the high-lift cam profile is deployed to feed the hot gas back into the cylinder for warm-up. As soon as the engine is warmed up, the valve gear switches back to the normal-lift profile.

The new diesel is equipped with what Mazda calls a "two-stage" turbocharger. The complex unit features an interconnected small turbocharger for low speed and a larger one for high-speed operation. They actually work in three stages—an intermediate stage is engaged when the two come into action, to pre-spin the large wheel for smooth upward transition.

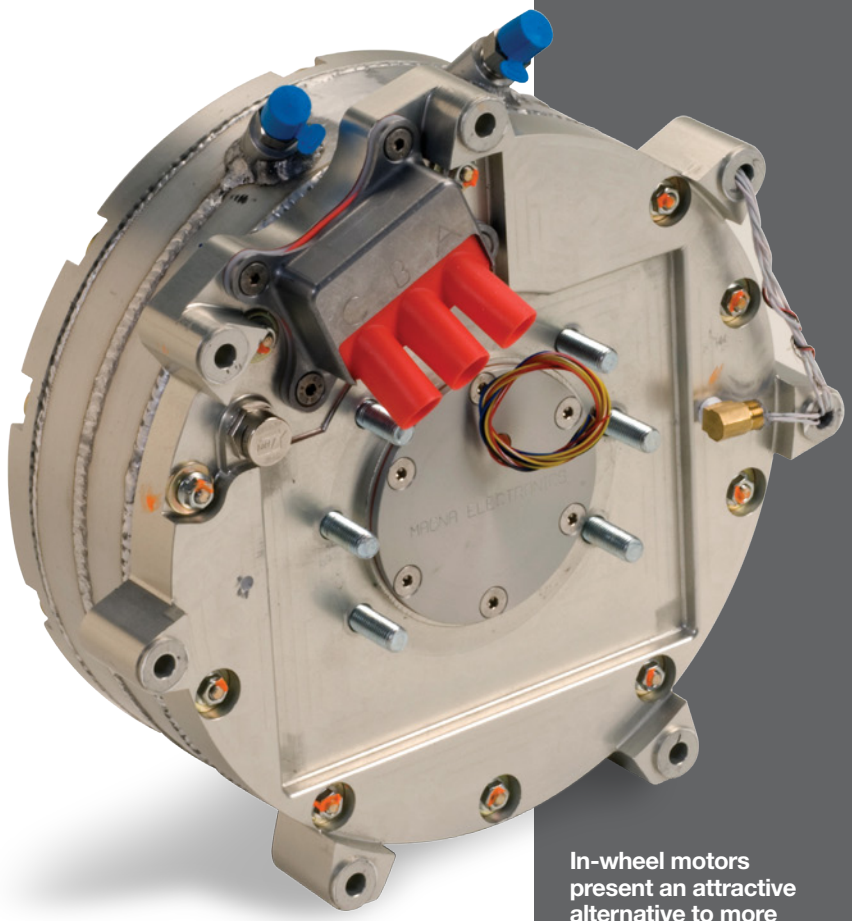
The low compression ratio allowed significant reductions in component weights and mechanical friction. The cylinder block is aluminum with cast-in iron liners. Unusual for a diesel, it employs an open-deck design, shedding 25 kg (55 lb) vs. the current Mazda CDI diesel. The cylinders are closely spaced with no large coolant passage between cylinders, except drilled holes.

The cylinder head is 3 kg (6.6 lb) lighter than that of the current CDI. Hitomi said the head is really a gasoline-like design and construction—maximum combustion pressure is about the same as a gasoline turbo of comparable size, he explained.

Like those of its gasoline near-cousin, the Skyactiv-D's internal reciprocating masses and frictions are reduced. The forged crankshaft and pistons are both 25% lighter than those of the CDI, and the new diesel's 56-mm main bearing journals and big-end bearings are 4-mm smaller than the current diesel's. AEI

Riding on in-wheel motors

Researchers analyze passive concepts and new mechatronic suspension systems to ensure vehicle comfort and safety when using in-wheel motors with different torque requirements.



In-wheel motors present an attractive alternative to more conventional EV concepts with a central electric motor, and they open the possibility to improve vehicle dynamics and handling. Shown is an in-wheel motor from Magna E-Car Systems with 50 kW, 135 N·m (100 lb·ft), and 95% efficiency.
(Magna E-Car Systems)

The R&D departments of almost every OEM in the world have the same goal: the electrified vehicle. While hybrids are seen as a bridge technology, electric vehicles (EVs) will decisively determine the future of transport. In-wheel motors present an attractive alternative to the more conventional concepts with a central electric motor, and they open the possibility to improve vehicle dynamics and handling Nevertheless, the automotive industry needs to cope with some unclear aspects regarding in-wheel motors before thinking about series production.

Packaging within the wheel and increased unsprung masses are two of the biggest difficulties engineers developing in-wheel motors are dealing with. Increased unsprung masses worsen the ride comfort and the driving behavior. The analysis of these two aspects in a wide range of vehicle speeds is important.

The wheel mass is correspondingly increased according to the weight of the electric motor. Examining the behavior of the motor mass for synchronous motors with interior magnets (IPM) and for asynchronous, or induction, motors (ASM) as a function of the driving torque in a range between 20 and 100 N·m (15 and 74 lb·ft), it is apparent that the driving torque and the motor power (at least for IPMs) have a big impact on the motor mass.

Besides the question regarding which motor type is best suited for a given application of in-wheel motors (*e.g.*, on demand or permanent drive), engineers face the issue of choosing the most appropriate suspension system to cope with the problems induced by increased unsprung masses.

With the aim of giving guidance for engineers developing suspension systems for in-wheel motor applications, researchers from **Graz University of Technology** compared the effectiveness of two passive and two mechatronic suspension systems intended to solve the problems related with the increased unsprung masses. They evaluated the performance of these systems for different road excitations, driving speeds, and unsprung masses.

The suspension candidates

Passive suspension systems do not need energy supply at all. This makes them attractive in hybrids or EVs, where, currently, energy saving is even more important than in vehicles with traditional combustion engines to increase driving range and make them attractive for typical vehicle customers and thus for series production.

The two passive suspension systems are a concept with an eccentric electric motor and a concept using the electric motor as damping mass. The eccentric concept can be used in vehicles with torsion beam axles. The electric motor is arranged eccentrically with respect to the rotation axis of the wheel. Because the distance between the electric motor and the wheel should be kept constant, this concept is more suitable for torsion beam suspensions. Its employment in conjunction with other axle types would lead to very complicated designs.

The damping-mass concept corresponds to that first introduced by **Bridgestone** in 2004. The electric motor is suspended over a spring-damper system on the wheel carrier. Using the electric motor as a damping mass, an additional degree of freedom is added to the vibrating system.

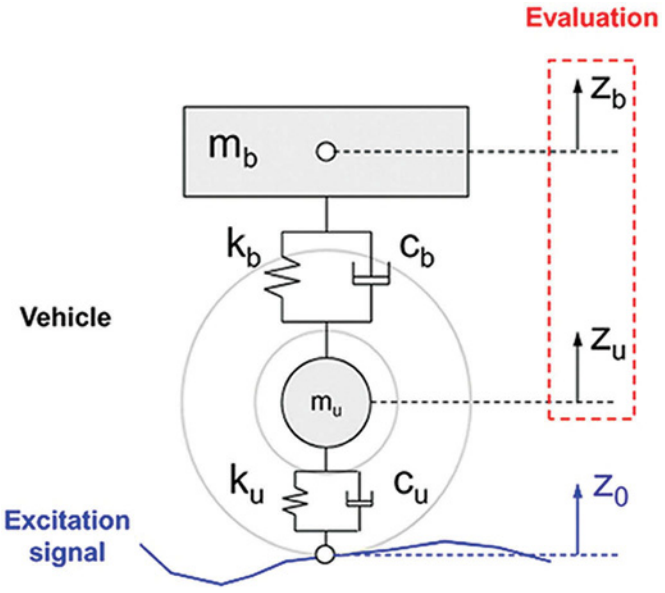
In modern mechatronic suspension systems, springs, dampers, antiroll bars, or even a combination of them are substituted by electronically controlled actuators, which provide significantly enhanced performance compared to passive systems.

Semi-active suspension systems fill the gap between fully active and passive systems. This kind of actuator can only dissipate energy from the system. In comparison, active systems are designed to supply energy as well. The difference with a passive damper lies in the possibility to change (within certain limits) the amount of energy to be dissipated for a given excitation speed adjusting the dissipating elements (*e.g.*, hydraulic valves).

A typical application for such systems is the adjustable shock absorber that has been introduced in numerous production vehicles. Unlike classical hydraulic dampers, the damper force depends on measured dynamic vehicle parameters. One of the most popular control strategies for such systems is the "semi-active skyhook damping."

Active electric damper systems have been studied in the past. Some designs use rotational electric motors in combination with a gearbox to reduce the torque requirement of the motor. More recently, the possible application of linear electromagnetic actuators has been investigated by some researchers. Although these latter systems have some benefits over their rotational counterparts (*i.e.*, no linear-to-rotational motion conversion, higher efficiency), they have a disadvantage in terms of power-to-weight ratio.

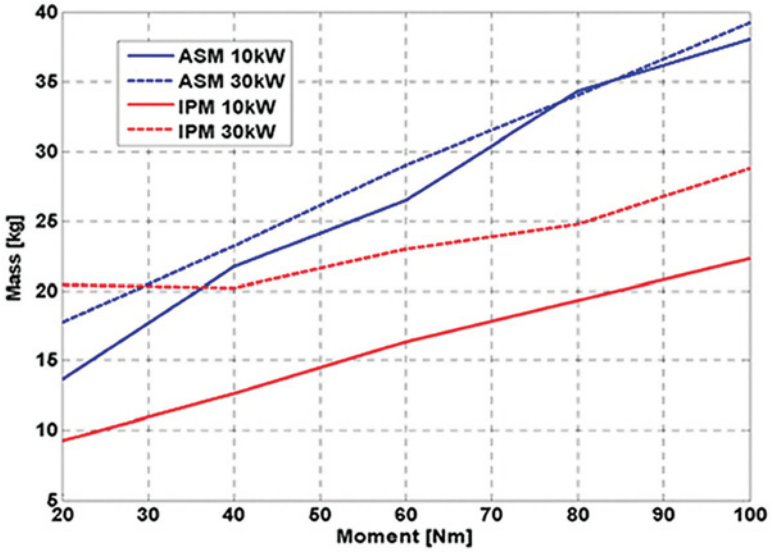
The design of electromechanical suspension actuators is affected by costs, weight, maximal power, and the

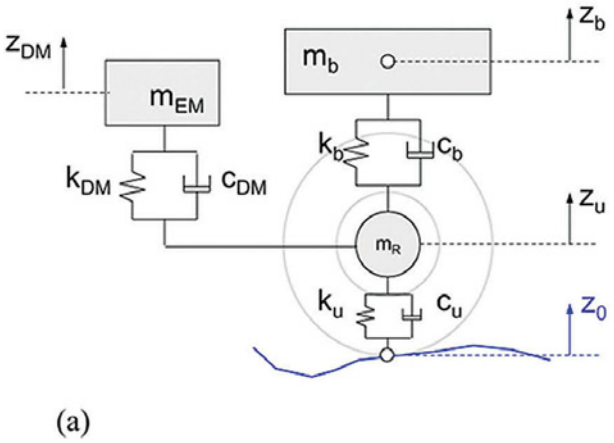


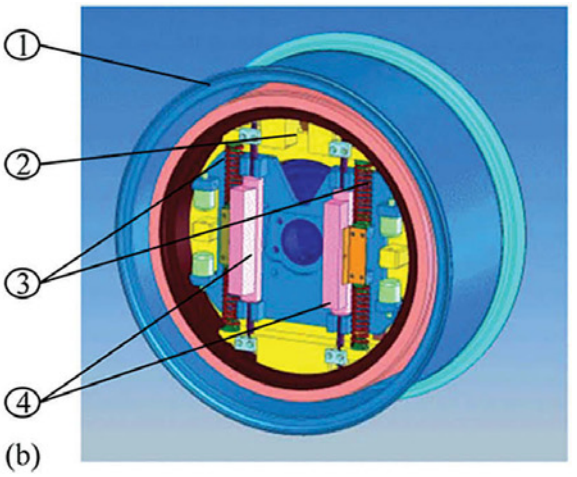
m_b = Sprung mass
m_u = Unsprung mass
k and c = Variables related with spring or damper
z_u = A given wheel
z_b = Vehicle body over that wheel

Above: Three stages of modeling and simulation of vertical vehicle dynamics.

Below: Mass of the electric motors as function of the driving torque (obtained with the simulations program developed at the Institute of Automotive Engineering at Graz University of Technology).







Dynamic damper mechanism with the electric motor being used as damping mass. (a) Schematic diagram: motor mass and spring and damper of the damping system. (b) Structure of the dynamic damper.

1. Wheel rim
2. Electric motor and flexible coupling system
3. Springs
4. Dampers

energy consumption required to achieve the desired performance. To maintain the electric motor as small as possible, the proposed damper actuator consists of a rotational ac motor and a planetary gearhead to reduce the required motor torque. The vertical movement of the tire is transformed into a rotation of a control arm around a fixed rotation axis at the vehicle body.

Furthermore, the rotation axis of the actuator is aligned with the rotational axis of the control arm. The required reference force calculated by the damper controller is transformed into a moment that is acting at the output shaft of the gear set. The actuator model consists of two main functional blocks: a first-order transfer function to represent the actuator dynamics and an actuator limitation block where power and moment constraints of the electric motor are considered.

Modeling the options

To assess ride comfort and driving safety, three main aspects were considered: development of a suitable vehicle model, selection and modeling of adequate excitation signals, and evaluation of the movement variables.

The vehicle was modeled in **MathWorks**' Matlab/Simulink as an 8-DOF (degrees of freedom) system—heave, pitch, roll, and vertical movement of the wheels and of the combustion engine and gearbox assembly. The combustion engine and gearbox were modeled as a mass suspended over a nonlinear spring and damper system.

A nonlinear semi-physical approach was used to model the components of a passive suspension system. Besides the springs and dampers, special attention was given to the tire model, which was depicted as a combination of a nonlinear spring and a system of cams to scan the road geometry.

The influence of tire pressure and centrifugal force acting on the tire belt was also considered. Those parameters not found in the specification sheet of the considered vehicle—the **Opel** Combo CNG 1.6—were obtained using an identification routine.

To analyze the performance of the considered suspension systems under different excitation conditions, three kinds of signals were described and modeled: a stochastic signal characterizing an average road type C based on the road description given in the international standard **ISO** 8608:1995(E), a harmonic signal with variable amplitude as a function of the excitation frequency, and a wideband deterministic signal (used also to validate the model).

The approach proposed in ISO 2631-1:1997(E) was employed to assess ride comfort. This standard takes the vehicle body acceleration as the starting point for comfort evaluation and states that the human perception of vibrations strongly depends on the frequency of excitation. Therefore, a series of filters with different transfer functions are suggested to weight the magnitude of vibration depending on its frequency (or frequency content in the case of non-harmonic signals), direction, and application location.

Since humans seem to be more sensitive to vibrations in the vertical direction z and to keep the model complexity within reasonable limits, the model and the simulations done in this work take only this vibration direction into account. And because road excitations in a range up to approximately 20 Hz are more directly transmitted to the passenger cell, simulations with harmonic signals are restricted to this frequency range.

The driving safety was evaluated using the so-called load factor, which relates the effective value of the dynamic contact force between tire and ground and the static contact force. Oscillations in the contact force between tire and road lead to fluctuations in the horizontal forces determining the handling behavior and vehicle stability. Therefore, it is desired to keep the contact force oscillations as low as possible.

To analyze realistic scenarios, ride comfort and vehicle safety were not analyzed together for all the signals. Ride comfort, when driving over a stochastic signal, can be taken as a

critical factor to evaluate a given vehicle, but it would not be seen as a dangerous situation *a priori*. However, ride comfort and driving safety are both relevant when driving over a border or a bump (wideband deterministic signal).

The results

Using the validated vehicle model, it was possible to show the effect of different wheel masses and driving speeds on ride comfort and driving safety. The results showed a big influence of the excitation signals and the driving speed on the performance of these systems. Therefore, a wide spectrum of driving speeds and excitation signals must be taken into account when designing a suspension system to cope with the problems induced by increased unsprung masses. Only in this way is it possible to evaluate the quality of a given suspension system to enhance ride comfort and driving safety.

The results obtained for the reference passive system show vehicle speed intervals (around 70 km/h [44 mph]) for which increased unsprung masses lead to an improvement, at least in ride comfort, of about 10%. For lower or higher speeds, however, the comfort of the vehicle with increased wheel mass was worse than for the unmodified vehicle. Based on this, the axiom regarding the negative influence of increased unsprung masses in vehicle comfort should be adopted with precaution.

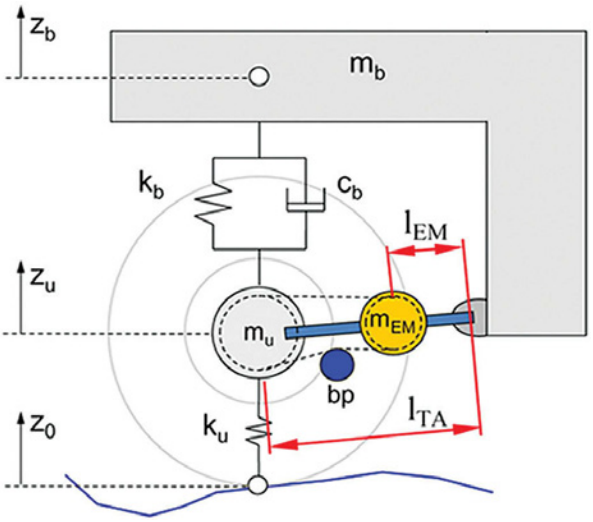
Both alternative passive concepts analyzed—the eccentric concept and the damping-mass concept—present advantages regarding the defined assessment criteria over the whole considered variation area. Nevertheless, their design is associated with other problems such as packaging, complex design, or suitability for a wide range of suspension designs (*e.g.*, steered axles).

Under the considered conditions, the damping-mass concept showed improvements in ride comfort up to 30 or 40% (stochastic and deterministic signals, respectively) and in driving safety up to 40% (deterministic signal) in comparison with the passive system. Increasing improvements in ride comfort and driving safety were noticed with larger damping masses.

The analyzed mechatronic systems present advantages in ride comfort (up to 10%) mainly for low speeds. It can be shown that, in general, the performance in ride comfort and driving safety of the active system is better than that of the semi-active system. However, the control strategies are based on widespread approaches found in the literature, which are not designed for applications with increased unsprung masses. Therefore, further investigations with adapted controller designs are needed.

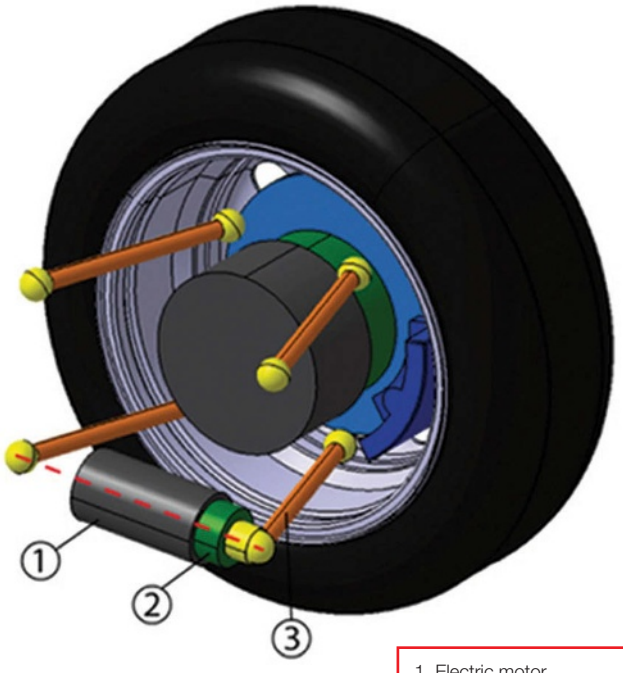
Of the alternative systems analyzed, only the damping-mass concept showed improvements in ride comfort and driving safety over the entire speed range, for all values of unsprung masses, and all considered signals. Based on this, as well as the fact that this suspension system does not need external energy supply, it can be seen as the most interesting alternative to cope with the problems induced by the increased unsprung masses of in-wheel motors if the problems regarding packaging can be solved. AEI

This feature is based on SAE technical paper 2010-01-1146 written by **Andrés Eduardo Rojas Rojas**, **Haymo Niederkofler**, and **Johann Willberger**, Graz University of Technology.



Above: A diagram of the eccentric concept used with a torsion beam suspension. The electric motor (yellow, motor mass) is placed at distance from the wheel, represented as the punctual mass m_u. Torque is transmitted to the wheel using a belt (a chain transmission is also possible). The belt pulley (bp) attached to the trailing arm guarantees the proper belt tension.

Below: Electric damper system topology. To maintain the electric motor as small as possible, the proposed damper actuator consists of a rotational ac motor and a planetary gearhead to reduce the required motor torque. The vertical movement of the tire is transformed into a rotation of a control arm around a fixed rotation axis at the vehicle body (red dashed line).



1. Electric motor
2. Gearbox
3. Transversal suspension arm

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Flash forward

Uncovering the hidden value of vehicle telematics.

by Charles M. Link, II, Chief Technology Officer, Hughes Telematics, Inc.

More than ever, consumers—especially Gen-Y buyers—appreciate the everyday benefits of "connected cars." Rapid adoption and growing demand mean telematics systems are well on their way to becoming standard equipment in tomorrow's vehicles.

High-demand developments such as smartphone application integration and connected navigation systems with up-to-date points of interest are already on the horizon. Not so obvious—but even more valuable to automakers, dealers, and drivers—are the services possible once vehicle connectivity is a mainstay.

That's bound to happen, and sooner rather than later, because the increasing complexity of vehicle electronics will mandate it. Some of today's vehicles run nearly 100 million lines of software code on between 70 and 100 electronic control units (ECUs); even entry-level cars have tens of millions of code lines. Cars in the near future may require two to three times that amount.

The costs of software-related recalls can be staggering. On average, it costs $75-95 per vehicle (plus time and inconvenience to the driver) to update the software in a vehicle. In 2007, there were more than 1.1 million software-related vehicle recalls, up sharply from the preceding years. As vehicle code becomes larger and more sophisticated, automobile manufacturers are looking at annual costs in the hundreds of millions for software-related recalls.

Telematics systems will provide a lower-cost alternative via remote vehicle software upgrades or "re-flashing" the vehicle. Much like the remote upgrading of wireless handsets, and even your personal computer, vehicles could be the next node on the network to be remotely upgraded. Instead of visiting the service center to upload firmware or software patches, vehicles will remotely download and install the upgrades through their telematics systems. Software downloads will occur over 3G or 4G cellular-data networks. Depending on the extent of the upgrade, and thus the size of the file, as well as the type and speed of the network, the upgrade process could be completed in a few minutes.

The firmware or software updates can be partitioned so that just the relevant programs or delta patches are downloaded, which can help shorten download time. If the vehicle loses its connection (as it drives through a tunnel, for instance), the reflashing technology ensures it will not need to reinitiate the complete download sequence. Finally, large numbers of vehicles can be updated simultaneously in batches, with quick reporting on the update success though telematics' two-way communications.

The cost-savings of remote reflashing vs. vehicle service center visits, although obvious, have not yet been quantified because they haven't been done in the automobile industry. However, logic suggests they will be cheaper, easier, and more reliable because of the effectiveness of this technology in another sector: machine-to-machine (M2M) software updates for mobile devices.

The Open Mobile Alliance Device Management (OMA-DM) group has a set of standards that permit FOTA (firmware over-the-air) updates. FOTA enables the safe and secure update of firmware or software on mobile devices and thus perhaps automobiles via telematics systems. One of the most useful aspects of FOTA is the ability to find differences between two sets of code and download just that portion, plus whatever additional code is necessary to implement the update. This code change is called the delta package. A smaller delta package means less bandwidth and quicker downloads. Thinking of FOTA in terms of only software updates is too narrow a view because OMA-DM and FOTA enable the remote delivery of new services or capabilities, thus reducing their time-to-market and increasing customer satisfaction.

More than ever, the ability to reflash vehicle software needs to be mainstream because of the introduction of new technology, particularly for electric vehicles.

EVs with enhanced telematics can quickly collect vast amounts of statistical and diagnostics data, driving and charging habits; provide crucial information on battery-life expectancy and optimal maintenance schedules; and is especially important with new software-based features like regenerative braking. These vehicle data can be gathered and analyzed regionally to help understand the impact of a variety of climate-based driving conditions and vehicle impacts. Driving conditions can impact battery charge life and lifetime, and telematics can provide information for optimizing both. Learning cycles can be significantly shortened—from years to months.

The bottom line is that automakers need to look at telematics systems not just as marketing gimmicks and revenue generators, but as sophisticated systems with boundless capacity to deliver consumer-relevant information and big cost savings. Companies that refuse to embrace this reality will find themselves at a competitive disadvantage. Ultimately they will subject their dealers and customers to frustrating software challenges as they develop the next generation of software-centric vehicles. 100

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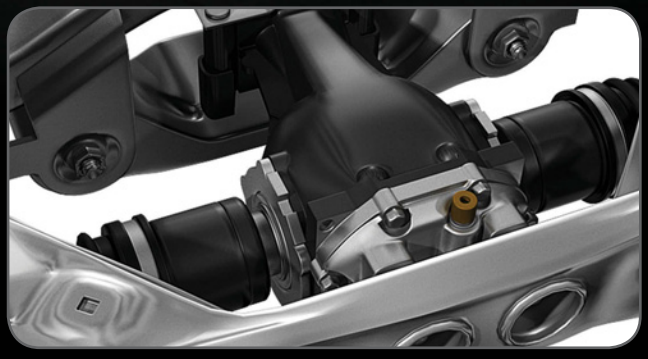

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