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A quarterly publication of **SAE** INTERNATIONAL and **SAEINDIA**

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brings body-in-
white expertise to
the global stage

Lightweighting

What's coming in
the campaign to
cut vehicle mass

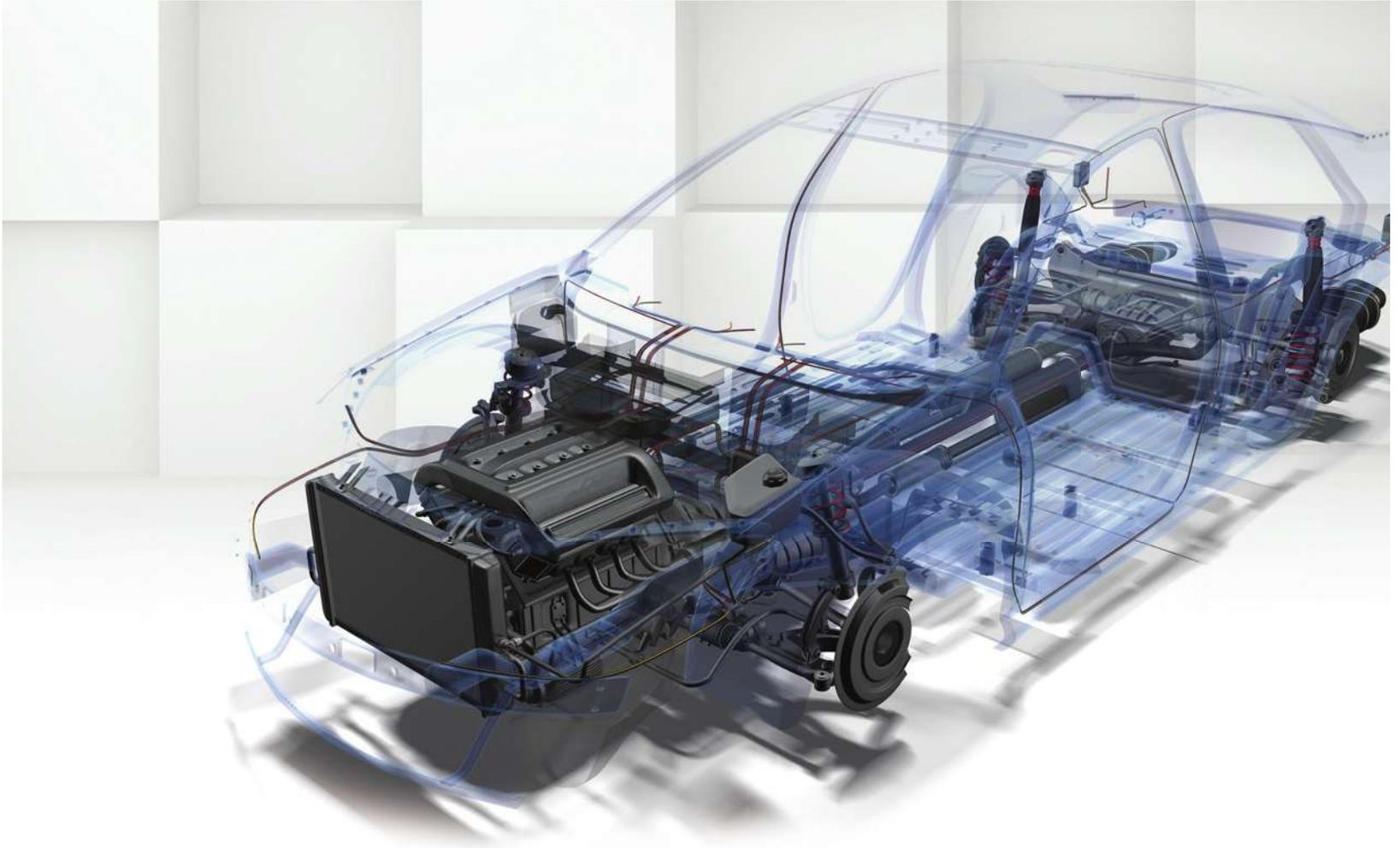
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CONTENTS

Features

37 Focus on advanced safety systems and human-factor interventions **AUTOMOTIVE SAFETY**

39 The impact of REACH on the aviation sector **AEROSPACE MATERIALS**

Considered the most comprehensive chemical-regulation legislation to date, REACH presents serious ramifications for the aircraft industry.

41 Lightweighting: What's Next? **AUTOMOTIVE MATERIALS | PRODUCT DEVELOPMENT**

Experts weigh in on the challenges and future enablers in the battle to reduce vehicle mass.

46 The best of COMVEC 2016 **COMVEC SPECIAL SECTION**

47 Optimizing waste heat recovery for long-haul trucks

48 Autonomous solutions in agriculture

49 Downsizing a HD diesel engine for off-highway applications

51 Zero-emissions electric aircraft: Theory vs. reality **AEROSPACE PROPULSION**



Cover

VDL Pinnacle Engineering India was established earlier this year to provide specialized engineering services for the production automation industry worldwide, particularly leveraging its expertise in body-in-white (BIW) engineering.



CONTENTS

Departments

4 Editorial

New developments advance SAE's mission

6 Focus

Enhancing SAEINDIA and its value to members

8 SAEINDIA News

8 Greater Noida hosts SUPRA SAEINDIA 2016

9 Automotive roundtables in Chennai and Pune

10 Inauguration SAEINDIA at Chennai and Cochin divisions

11 AWIM Master Teacher Training Program in Pune and Solapur

11 SAE Trek in Pune and Chennai

12 INNOVISTA 2016 in Dindigul

13 Industry News

13 Bosch expands development activities in India

13 Dassault Aviation, Reliance Infrastructure form strategic partnership

13 Indian JV offers engineering services for BIW weld shops

14 Mahindra connects vehicles via cloud-based technology platform

15 Technology Report

15 Nissan unveils variable-compression-ratio ICE for 2018 Infiniti production model **AUTOMOTIVE POWERTRAINS | PROPULSION**

17 Inside Porsche's new V8 and V6 powertrains **AUTOMOTIVE POWERTRAINS | PROPULSION**

19 GM, Honda execs agree: Higher octane gas needed to optimize ICE efficiency **AUTOMOTIVE PROPULSION | FUELS**

20 Optimizing engine oil warm-up strategies for 'real-world' driving **AUTOMOTIVE POWERTRAINS | PROPULSION**



21 Eaton demonstrates waste-heat recovery, variable valve actuation for HD diesels **OFF-HIGHWAY HEAVY-DUTY POWERTRAIN**

23 Mazda's 2017 G-Vectoring Control brings dynamic refinement **AUTOMOTIVE CHASSIS**

24 Tenneco's predictive active ride control may doom the anti-roll bar by 2021 **AUTOMOTIVE CHASSIS**

26 More details emerge of Citroën's new 'hydraulic cushion' suspension **AUTOMOTIVE CHASSIS**

27 JLR prepares to leave the road — autonomously **AUTOMOTIVE AUTONOMOUS TECHNOLOGY**

29 In search of higher-energy-content batteries **AUTOMOTIVE ELECTRONICS**

30 SAE Battery Standards committees prepare for next-gen chemistries **AUTOMOTIVE ELECTRONICS**

30 Making Multiphysics fast and convenient **AUTOMOTIVE SOFTWARE | SIMULATION**

32 OTA updating brings benefits, challenges **AUTOMOTIVE ELECTRONICS | SOFTWARE**

33 Full-electric drivetrain for HD vehicles the result of supplier alliance **OFF-HIGHWAY ELECTRIFICATION**

34 Automotive influence on off-highway cabs **OFF-HIGHWAY INTERIORS**

35 Self-piercing rivets shoot for vehicle-lightweighting applications beyond aluminum **AUTOMOTIVE MATERIALS**

56 Global Vehicles

56 Aero-slick Land Rover Discovery sheds 1058 lb, gains features

58 With 2017 Fusion Sport, Ford pushes further toward Audi

60 Citroën unveils CXperience concept at 2016 Paris show

61 Volvo S90: Niche for now, but...

63 Companies Mentioned, Ad Index

64 Q&A

Bob Lutz on what makes a great engineer

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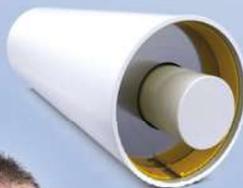
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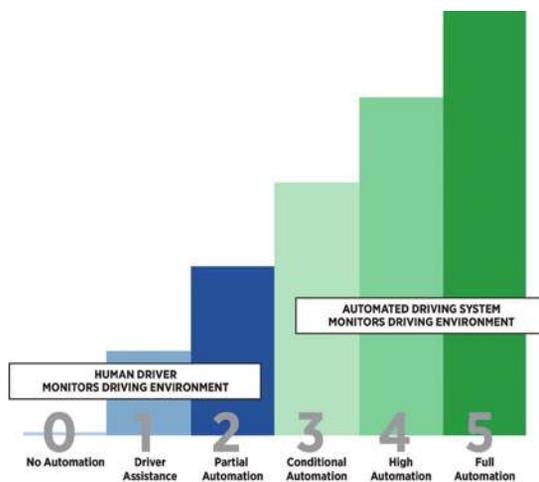
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New developments advance SAE's mission

If you're reading this magazine, you probably don't need me to explain the scope of SAE's impact in the automotive and aerospace sectors. But two recent developments regarding SAE's role "beyond" engineering do merit a special callout, I think.

With automated-driving technology development occurring at a furious pace and news of some recent advance or collaboration now a daily expectation, it was a matter of no small importance when the **U.S. Dept. of Transportation (DoT)**, as part of its first-ever policy guidance regarding testing and deployment of vehicles using automated-driving technology, validated SAE Standard J3016 as the global industry reference for defining six levels of autonomy.



SAE Standard J3016 now is the official definition for the six levels of automated driving.

Descriptions and definitions of autonomous technology have until now been all over the map—and the DoT determined that SAE's six-level definition is logical and straightforward enough to use as an industry-wide benchmark.

The DoT guidance document, "Federal Automated Vehicles Policy," states that manufacturers are responsible "to determine their system's AV [automated vehicle] level in conformity with SAE International's published definitions." This applies to both test and production vehicles. From there, the **National Highway Traffic Safety Admin.** (NHTSA, the other chief U.S. transportation regulatory body) will review the manufacturers' automation-level designations and advise them if the agency disagrees with the level assigned by the manufacturer.

The DoT's validation of SAE J3016 as official

guidance is important. Previously, NHTSA itself, as well as other agencies, OEMs and suppliers, at times employed confusing and occasionally contradictory definitions for autonomous technology and vehicle behavior. Now, SAE J3016—first published in January, 2014—provides common taxonomy and definitions to be used by all. It's a significant and vital step in "getting everyone on the same page," regarding the foundation assumptions about the pivotal automotive advance of this generation.

SAE didn't stop there.

In a groundbreaking collaboration that could serve as a template for partnerships to help the government react more like private industry to swift-moving technology development, SAE and the **U.S. Army's Tank-Automotive Research, Engineering and Development Center (TARDEC)** in September announced the formation of the non-profit **Defense Automotive Technologies Consortium**, or DATC, for the purpose of reducing the time and cost of technology transfer and to minimize the bureaucracy and risk typically associated with government contract awards.

Why DATC? The U.S. Army recognizes its hoary procurement process can't hope to keep up with the machine-gun rapidity of new, electronics-dominated automotive advances—including those related to automated-driving; that includes the particularly sensitive area (for the Army) of cybersecurity. So the Army enlisted SAE to facilitate collaboration with private industry to more quickly and cost-effectively contract for the latest ground-vehicle technologies.

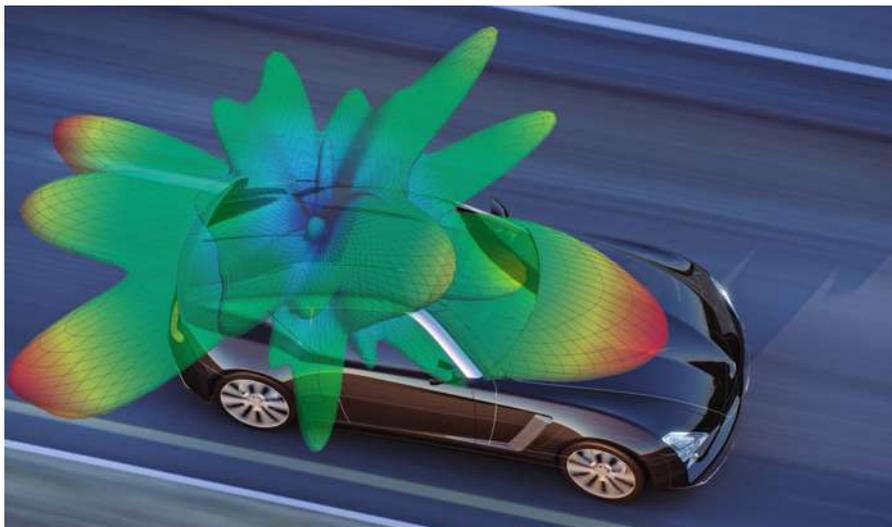
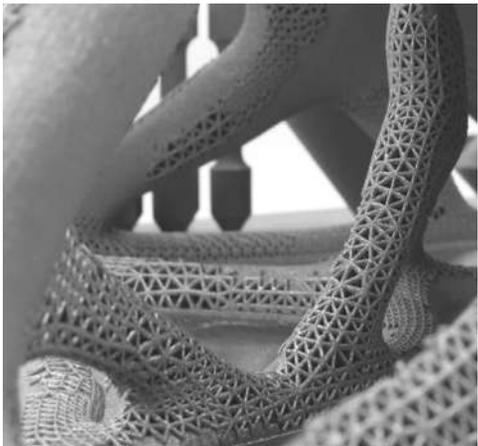
The new consortium aims to provide private, non-profit and academic organizations "unprecedented" access to U.S. government projects, while providing revenue opportunities and cutting procurement "red tape." And DATC also is intended to entice suppliers by drastically reducing the traditional financial risk of pursuing government business: DATC-approved program awards cannot be protested and are not subject to Defense Audit Agency audits.

SAE International President Dave Schutt summarized it by saying DATC is "a seminal program that will provide an entirely new value proposition to the automotive industry and advance SAE's mission. It's a big win."

Make that two big wins for SAE in 2016. Everyone involved with the organization should be gratified to see SAE establishing a leading-edge role in advancing new technology.

Bill Visnic, Editorial Director

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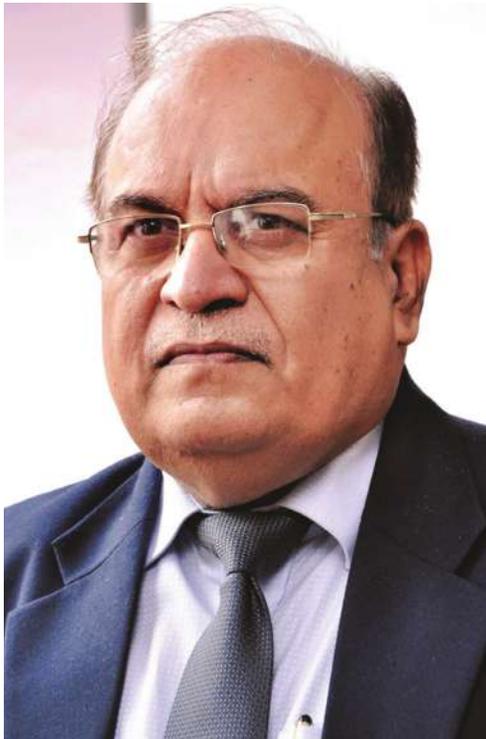
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Enhancing SAEINDIA and its value to members

SAEINDIA members, welcome to the new era! A new Management Committee and Boards took charge in July and the following months have been filled with several key events and actions from the SAEINDIA team.

In October, the SAE International Presidential delegation that included current SAE President Mr. Cuneyt Oge and his wife Mrs. Margo Oge and the organization's



Dr. R.K. Malhotra
President, SAEINDIA

Global Affairs Specialist, Mr. Murli Iyer, met with leading auto-industry patrons and prestigious engineering institutions during a 10-day tour of India. The presidential delegation's visit was an important milestone for the SAEINDIA family in this year.

The Blue Ribbon CxO Conclave in Chennai and the ISFL-SAE Conference, "Fuels, Lubricants & Emissions: BS IV to BS VI" in Gurgaon—organized by **Indian Oil** and SAEINDIA—offered a fine networking platform for industry leaders to connect with our International President. Mr. and Mrs. Oge

also delivered lectures in several key institutions in Bengaluru, Chennai and Faridabad, speaking about what the global auto industry may look like in the year 2050.

Next, SAEINDIA entered into a memorandum of understanding (MoU) with **Chitkara University** in Chandigarh to conduct the virtual Baja SAEINDIA event for the next three years and provide accommodation for the teams.

September saw one of our patrons, Dr. Pawan Goenka, Executive Director of **Mahindra & Mahindra**, presented with the Medal of Honor at the **FISITA** World Congress in Korea. At the same event, my predecessor, Dr. Aravind Bharadwaj, was inducted into the select club of global SAE Fellows. Congratulations to them on behalf of the entire SAEINDIA family for achieving these honors.

Also in September, we partnered with **NASSCOM** in Bengaluru for the Design & Engineering Summit 2016. SAEINDIA offered a deep-dive session on the automotive and aerospace industries at the summit. Sessions by Mahindra and **TCS** were well-appreciated, with more than 100 attendees at the NASSCOM Forum. The aero session centered around the future of the aerospace industry in India, with panelists from **Safran**, **Honeywell** and **GE Aviation**.

Finally, I will mention that SAEINDIA is experiencing another wave of fresh enthusiasm, as the newly elected Management Committee and Board members combine with a new leadership team in our offices. Mr. K. Venkataraj, who brought vast international experience when he joined the organization in September, will be at the helm of affairs. Mr. R. Subramaniam, with his extensive experience as CFO and company Secretary, will help us upgrade the finance, legal and audit functions of our office. With the appointment of these two professionals, the SAEINDIA administration will deploy more dynamism and best practices in conducting our business.

This renewed energy and enthusiasm will deliver more value to you, our members, with more events and conferences that have *you* as the focus. Expect more!

Wishing you an eventful 2017.

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SAEINDIA

News

Greater Noida hosts SUPRA SAEINDIA 2016

The fifth edition of SUPRA SAEINDIA, India's largest student formula-car competition, kicked off with the oath ceremony at the Formula 1 track at Buddh International Circuit in Greater Noida on July 4. The oath for the student formula competition was administered by Mr. Balraj Bhanot, Chairman, Transport Engineering Division Council (TEDC) of BIS, along with Mr. P K Banerjee, Convener, SUPRA SAEINDIA 2016.

SUPRA, organized annually by SAEINDIA, provides a platform for students to apply their engineering skills to design and construct a Formula-category race car per defined performance and safety specifications. SUPRA SAEINDIA 2016 was comprised of a series of static and dynamic events spread over five days, concluding with a final endurance test and a valedictory function on July 9.

Static events included:

- Marketing presentation
- Engineering design
- Cost evaluation

Dynamic events included:

- Acceleration performance
- Skid-pad performance
- Autocross performance
- Fuel efficiency
- Endurance

The SUPRA SAEINDIA 2016 events encompassed a total of 1000 points distributed evenly in the different static and dynamic events.

Narain Karthikeyan, the first Indian Formula 1 driver, visited SUPRA 2016 on the penultimate day of the event to interact with and encourage the engineering students, as well as detail real-world aspects of competing in global motorsports.

This year, the event saw record participation from 3500 engineering students and 125 teams. **Maruti Suzuki India** was the title sponsor of SUPRA India 2016 for the consecutive fifth year, which also saw sponsorship from **Total, BPCL, Castrol, Shell, AVL, Siemens, Altair, Ansys, MRF, CEAT, GKN, Horiba, Dassault Systems, Hindustan University, Tripti Hospitality, Eleation, Continental** and **Viper Hobbies**.

SAEINDIA, the Indian chapter of the Society of Automotive Engineers, organizes the event that sees students from



Oath-taking ceremony.



Vehicle inspection.

engineering colleges across the country battle to apply their technical knowledge by conceptualizing and developing a formula racing car. Governed by a standard rulebook, Formula SUPRA requires teams to build a single-seat racer using an engine with a maximum capacity of 600cc. With numerous other guidelines over the construction, dynamics and safety of the vehicle, students design the car with various computer-aided tools like **CATIA, Unigraphics, Ansys** and others.

SUPRA SAEINDIA 2016 was held over six days (July 4-9); of the record number of 125 teams, 46 qualified for the technical round and 26 made it to the final round in which the cars faced off in dynamic tests.



Static and dynamic events.



Mr. Narain Karthikeyan.



Dignitaries address the valedictory ceremony.

The event was judged by a panel comprising 200 eminent experts from the automotive industry, including four international experts—Mr. Benjamin Moeller, Mr. Christian Thomas Amersbach, Mr. Christoph Martin Beisswanger from Germany and Ms. Anastasia Potrashkova from Russia.

The competition was narrowed to 26 teams in the final round, with 12 cars completing the entire race of five laps of the 5.5-km (3.4-mile) main track of the Buddh International Circuit. Before the start of the race, drivers were briefed; following was a track walk so drivers could become familiar with the main endurance track.

The SUPRA SAEINDIA 2016 ended with the valedictory ceremony. The valedictory session was attended by chief guest, Dr. David Schutt, CEO, SAE International; Mr. C V Raman, executive director, Engineering, Maruti Suzuki India; Mr. R S Kalsi, executive director, Marketing and Sales, **MSIL**; Dr. Aravind Bharadwaj, president, SAEINDIA and Mr. Prashant K. Banerjee, deputy executive director (Technical), **Society of Indian Automobile Manufacturers (SIAM)**. Other dignitaries included Mr. Murli Iyer, global advisor, SAE International, Mr. I V Rao, executive advisor, MSIL and other representatives from the automotive industry.

These links detail SUPRA SAEINDIA 2016's overall winners and individual-event award-winners:

http://suprasaeindia.org/pdf/SUPRA_SAEINDIA_2016_Overall_Rankings.pdf

http://suprasaeindia.org/pdf/SUPRA_SAEINDIA_2016_Award_Winners.pdf



Award ceremony.

Automotive roundtables in Chennai and Pune

SAEINDIA, in association with **Siemens PLM Software**, successfully conducted two automotive roundtables (ART) in July in Chennai and Pune.

The automotive roundtable sessions were well-attended, with more 120 senior industry professionals in attendance between the two locations. The deliberations during the roundtables provided many insights on the current industry challenges as well as projections regarding the way forward for developing smart, sustainable and safe vehicles.

Dr. Arunkumar Sampath, General Manager, **Mahindra & Mahindra**, kicked off the proceedings at Chennai and spoke about industry trends, presented a technology update regarding new developments in autonomous and connected vehicles and design changes likely to emerge in the foreseeable future. He also identified the challenges faced by the industry with a change in regulations from BS IV to BS VI, which he said will bring about a sea of change in the mobility industry.

Dr. Aravind Bharadwaj, Sr. Vice



Dr. Aravind Bharadwaj addresses the event.

President and Head – Technology (TPDS), Mahindra & Mahindra, then moved the discussion forward by sharing his perspective of the challenges and implications for the industry. The two Mahindra executives set the tone for the panel discussion, which followed the opening address; the panel was moderated by Mr. Gautam Dutta, Sr. Director – Marketing, Siemens PLM Software and featured the following eminent panelists: Dr. P Sivakumar, Director, CVRDE; Mr. Prahalada Rao, Vice President – Product Planning,

Mahindra & Mahindra; Mr. T Sarangarajan, Sr. Vice President – Operations, **TAFE**; Dr. Bade Simhachalam, Senior General Manager - Corporate Technology Center, **Tube Investments of India**; Dr. Sandhya Shekhar, Knowledge and Innovation Strategies Advisor and Author, Independent Director on Boards of **Bimetal Bearings and IP Rings**; and Mr. Rajendra Khile, Deputy General Manager – Technical Regulations, **Renault Nissan**.

The lively panel discussion brought out various facets of developments in the industry, with digitalization and increased content of electronics in passenger vehicles and trucks making them closely connected and integrated. This was followed by a presentation by Mr. Aiyappan Ramamurthi, Director – Technical, Siemens PLM Software on the value of PLM for executing program innovation, thus providing a logical conclusion to the preceding discussions.

The event then moved to Pune, where Mr. Ramesh S. Pasarija, Deputy

SAEINDIA

News



Panelists in discussion during the event.

Director, SAEINDIA Western Section, welcomed the gathering and gave a holistic presentation on the given topic, providing a multi-dimensional view of what is in store and likely new developments. Mr. Pasarija then handed over to Mr. Sachin Sanghi, Director – Technical, Siemens PLM Software, who moderated the panel discussion. As in the initial roundtable

session in Chennai, an eminent set of panelists brought their vast experience to weigh in on the challenges and possibilities for the industry: Ms. Rashmi Urdhawareshe, Director, Automotive Research Association of India (ARAI); Dr. Venkat Srinivas, Vice President & Head - Engineering & Product Development, Mahindra & Mahindra; Dr. Anuradda Ganesh, Director – Advanced Engineering, Cummins Technologies India; and Mr. Shekhar Malani, Managing Director, Devise Electronics Pvt. Ltd.

Upon conclusion of the panel discussion, Mr. Sachin Sanghi spoke about the value of PLM in enabling automotive OEMs and suppliers to thrive in an era of smart innovation. Mr. D. Seshadri, Executive Director, SAEINDIA, then brought the session to a close and thanked all the participants.

The two roundtables at Chennai and Pune provided the participants interesting perspectives as well as ample insights and food for thought about the future.

Inauguration SAEINDIA at Chennai and Cochin divisions

On August 13, 2016, the SAEINDIA Chennai Division under Southern Section (SAEISS) was inaugurated. Mr. Khader Basha, Chairman, SAEISS - Chennai Division welcomed all the members of the SAEINDIA Southern Section for the inaugural function. Dr. E. Rajasekar congratulated the SAEISS - Chennai Division Management Committee Members and introduced them to the Section Management Committee members.

Mr. K. Ganapathy Subramaniam, Divisional Manager Marketing, Simpson & Co Ltd., Chennai, invited the dignitaries, Mr. S. Sriraman, Chairman - SAEISS, Dr. E. Rajasekar, Secretary - SAEISS, Mr. T.R. Sathyanarayanan, Treasurer - SAEISS, Mr. S. Shanmugam, Director DDIPL and Mr. M. Khader Basha, Chairman – SAEISS Chennai Division



Mr. M. Khader Basha, Scientist, CVRDE, Chairman – SAEISS Chennai Division welcomes the gathering.

and Mr. R. Senthilkumar, Secretary - SAEISS Chennai Division, to take the dais. Dr. S. Sundareshan, Director General R&D (Retd), CVRDE, expressed his gratitude for the inaugural function of Chennai Division. Mr. R. Senthilkumar, Secretary Chennai Division, thanked all for attending the inaugural function and making the event a success.

The SAEINDIA Cochin Division under Southern Section (SAEISS) Inauguration ceremony was organized on August 27, 2016, at Rajagiri College of Engineering & Technology in Cochin. Dr. Thankachan T. P., HOD, Mechanical department, RSET, welcomed all the dignitaries and participants to the inauguration of the Cochin Division and all the dignitaries inaugurated the Cochin Division by lighting the lamps. Mr. S. Sriraman, Chairman—

SAEISS, gave the inaugural address. Dr. E. Rajasekar introduced all the MC members of Cochin Division to the participants. He also wished them well for their future activities and the growth of Cochin Division.

Mr. Benkim B A, Treasurer, SAEISS - Cochin Division, welcomed the gathering and introduced the speaker, Dr. E. Rajasekar, to the participants and handed over the session to him for the lecture on “Automotive Sensors and their Applications;” the lecture was productive for the members since it discussed many modern sensors and their functions. Mr. Francis Augustine Joseph thanked the speaker for his lecture and Dr. Manoj Tharyan, faculty advisor, SAE Collegiate club of RSET, presented him with a memento as a token of gratitude.



Cochin Division Inauguration - Mr. S. Sriraman, Chairman - SAEISS lighting the Kuthuvilakku.

AWIM Master Teacher Training Program in Pune and Solapur

The AWIM (A World In Motion) Master Teachers & Volunteers Training Program (MTTP) was conducted July 8-9, 2016, at the **Automotive Research Association of India** in Pune. The training focused on the Skimmer and Jet-Toy aspects of the AWIM curriculum. There were approximately 75 participants that included industry and student volunteers and teachers for the training.

Mr. Ramesh. S. Pasarija welcomed all the participants for this training program that was inaugurated by chief guest Dr. David Schutt, CEO, SAE International and Mr. Murli Iyer, Executive Advisor - Global, SAE International. Guests on the dias during the inauguration included Mr. Shrikanth R. Marathe, Immediate past Chairman of SAEIWS; Prof. P. B. Joshi, Vice Chair, Student Activities of SAEIWS; Mr. B. V. Shamsundara, Treasurer of SAEIWS; and Dr. K. C. Vora, Coordinator of SAEIWS.

The Jet-toy training was conducted during the event's first day and Skimmer training was conducted on second day. The Jet-toy master trainers were Mr. Manoj Girhe from **John Deere** and Mr. Aatmesh Jain from ARAI. Master Trainers for the Skimmer were Mr. Rahul Gujar and Mr. Shrikanth Sampath from **Eaton**. Teams of four members were established, comprised of a minimum of one teacher and one student volunteer and two industry volunteers. The training started with the introduction of SAE International and SAEINDIA, explaining the different activities conducted by these societies for different categories of members.

After the initial demonstration, the teams prepared the Jet-toy and Skimmer. Teams were asked to design new sail patterns different from conventional designs. They were also provided with chart papers to prepare presentations with a theme for their Jet-toy and Skimmer. Each team tested its Jet-toy and Skimmer on corresponding tracks for distance, load-carrying capacity, speed, accuracy, maximum time and



Toys prepared during the event at Solapur.



Dr. David Schutt, CEO of SAE International, inaugurates the Pune event.

turning ability. The results for each round were noted by respective teams during the training program. Master Trainers presented on track description and scoring, along with rules and guidelines for the competition. They also presented science notes on simple physics for school children.

After the training programs, on July 23, 2016, a parent orientation program was organized at The Orchid School, Pune. Mr. Sagar Murugkar, Ms. Dipika Nabodiri and other volunteers from Cummins participated in parent orientation. There was an AWIM activity presentation and a short film on AWIM for all parents and students. The agenda for this orientation was to invite more student participation for AWIM activity, with queries regarding AWIM answered by the volunteers.

A similar orientation was conducted successfully on Aug. 27, 2016 at the Valentine Circle School in Solapur, with 30 participants that included student volunteers and teachers for this training and went on to train students in the respective schools in July, August, September and October.

SAE Trek in Pune and Chennai

The Pad-Marg - SAEIWS Trek, a one-day program that blends adventure and learning, is an initiative of the SAEINDIA Western Section for its members. The second trek in this initiative occurred in August, 2016, from Vetal Hill to Chaturshrungi Hill and back.

The program takes place at scenic trekking locations that provide a great sense of adventure and bonding with nature, as well providing the opportunity for instructional learning. In the second edition of program, participants collected plastic waste bottles on the hill and sent them for recycling. Participants also took a test on general

automotive engineering.

Participants gathered at the Vetal Hill Hanuman Temple, trekked to Chaturshrungi Hill and then returned. Vetal Hill is a prominent hill in the city limits of Pune and is the highest point within the city limits. The winners of the automotive engineering test were Mr. Thomas Cherian and Mr. Tarun Ranjan. Both were awarded a gift in the form of books, presented by Mr. Narahari P. Wagh, Secretary, SAEINDIA Western Section.

The SAEINDIA Southern Section organized an SAE TREK at the **Knowledge Institute of Technology** in Salem on August 27, 2016. A total of 35

students from 15 different college SAEISS clubs participated. The one-day program began with a welcome address from Knowledge Institute of Technology and the head of the department welcomed the resource person and MC Member SAEISS.

Mr. R. Armstrong, MC Member - SAEISS and Mr. S. Shanmugam Director, DDIPL, addressed the host college and gave brief introduction about SAE Trek. The SAEINDIA Southern Section thanked the Knowledge Institute of Technology for hosting the prestigious Trek program on the college premises and Mr. S. Shanmugam presented the

SAEINDIA

News



Team at Chaturshrungi Hill.



Team at Yercaud Hills.

memento to the college.

After the inauguration for the Trek Program, the first session, Engineering Design, was started by Mr. S. Shanmugam and he explained the various design fundamentals to the participants. Participants then were divided into seven teams. Mr. S. Shanmugam

explained the objectives and the purpose of the challenge and the requirements and expectations for each team.

Teams designed toys using engineering fundamentals to complete the task in the given time. Teams then demonstrated their designs for the resource representative, with students making

note of various parameters to compare the results.

On the second day, all participants, along with volunteers, trekked to Yercaud Hills. Mr. S. Shanmugam, Mr. R. Armstrong and Dr. E. Rajasekar distributed a certificate to the participants after the trek.

INNOVISTA 2016 in Dindigul

The SAEINDIA Southern Section's Madurai Division organized a state-level engineering college student project competition, INNOVISTA 2016, in September at PSNA College of Engineering and Technology in Dindigul, in association with TAFE in Madurai.

INNOVISTA 2016 is a project competition jointly organized by SAEINDIA Southern Section, Madurai Division and Tractor and Farm Equipment (TAFE), Madurai.

During the inauguration Mr. V. Srinivasan, Sr. Associate Vice-President, TAFE, Mr. Sivakumar, General Manager, Materials, TAFE, Ms. Chhaya Balasubramanian, HR Manager, TAFE and other dignitaries from colleges took seats on dais. Mr. V. Srinivasan inaugurated INNOVISTA 2016 by lighting the kuthuvillaku with the other dignitaries and he delivered the inaugural speech.

Dr. M. Uthayakumar, treasurer, SAEISS in Madurai, delivered the welcome address. The TAFE Manager of human resources, Ms. Chhaya Balasubramanian, then set the context of the program and the Presidential address was delivered

by Dr. N. Mahendran, Principal-in-charge, PSNACET. Dr. D. Vasudevan, HOD/Mech. Eng. PSNACET and Mr. Sivakumar, General manager, TAFE, felicitated the gathering, while Dr. Kannan Rajendran, Secretary of the SAEISS Madurai division, delivered vote of thanks. An exclusive live demonstration of tractors was performed by Mr. Arul Anandakumar and Mr. Arsad of TAFE.

For INNOVISTA 2016, a total of 160 abstracts were received and 36 projects were selected for final display at the PSNA College of Eng. & Tech. in Dindigul. The officials from TAFE toured the project display hall and evaluated the student projects. The top three teams were awarded with a memento and cash prize. The next five top-placing teams were presented with consolation prizes.

In the concluding session, Mr. V. Srinivasan brought the winning teams to TAFE for a special presentation session and he encouraged them to take the projects to the next level. All INNOVISTA 2016 participants were presented with participation certificates.



Dignitaries in attendance at INNOVISTA 2016.



Mr. V. Srinivasan, TAFE, presents inaugural speech during INNOVISTA 2016.

Bosch expands development activities in India

Global technology and services supplier **Bosch Group** is strengthening its presence in the Indian growth market. In 2016, Bosch plans to invest more than 100 million euros in its Indian manufacturing and development locations, according to Peter Tyroller, the member of the Bosch board of management responsible for the Asia Pacific region.

The bulk of this investment is directed to expanding the Bosch Adugodi location in Bangalore, southern India. In the last two years, Bosch has invested nearly 50 million euros to turn its oldest Indian manufacturing location into a high-tech development center.

In September, Bosch inaugurated two new facilities that offer space for 20 state-of-the-art research and test labs. More investments are planned to keep expanding the Adugodi location in the coming years.



Two new buildings were recently inaugurated at the Bosch Development Center in India.

India is an important development hub for Bosch. “The expansion of the Adugodi site illustrates how important India is for the Bosch Group as an innovative location,” said Tyroller.

Bosch’s development activities in India are the most comprehensive outside Germany, according to the company, with more than 14,000 associates currently employed in this area. Around 3000 of them work at the new facilities in Adugodi, which were planned with a special focus on creating an inspiring work environment, says Bosch.

Bosch engineers in India develop solutions in a number of areas, including driver assistance and security systems, data mining, and software solutions for the Internet of Things (IoT). As a result, Bosch is gaining significance as a software employer in India. This year the company plans to hire 3500 local graduates.

With a total of more than 30,000 associates in India, Bosch is one of the country’s largest employers.

Dassault Aviation, Reliance Infrastructure form strategic partnership

France’s **Dassault Aviation** and India’s **Reliance Group** announced in late September 2016 the creation of a joint venture (JV) in India called **Dassault Reliance Aerospace**.



The Dassault Reliance Aerospace JV will be a key player in the execution of offset obligations, as a part of the 36 Rafale fighter jet purchase agreement signed between France and India in late September 2016.

With this announcement came news that the Dassault Reliance Aerospace JV will be a key player in the execution of offset obligations as a part of the 36 Rafale fighter-jet purchase agreement that was signed between France and India on September 23, 2016 and is valued at around €7.87 billion, or about Rs. 59,000 crore. The agreement has a 50% offset obligation, which is the largest-ever offset contract in the history of India, according to a statement from the two companies.

The JV will support India Prime Minister Narendra Modi’s “Make in India” and “Skill India” policies and develop major Indian programs with high levels of technology transfer to benefit the entire aerospace sector.

The proposed strategic partnership between Dassault and Reliance also will focus on promoting research and development projects under the Indigenously Designed, Developed and Manufactured (IDDM) program, a new initiative of India’s Defense Minister Manohar Parrikar.

“The formation of this joint venture with Reliance Aerospace led by Anil Ambani’s Reliance Group illustrates our strong commitment to establish ourselves in India and to develop strategic industrial partnerships under the ‘Make in India’ policy promoted by the Indian Government,” said Dassault Aviation Chairman and CEO Eric Trappier.

“We are delighted to partner a world leader in aviation like Dassault Aviation, and a visionary leader like Eric Trappier,” said Chairman Anil Dhirubhai Ambani. “This is a transformational moment for the Indian aerospace sector and for Reliance Infrastructure’s subsidiary Reliance Aerospace.”

Indian JV offers engineering services for BIW weld shops

Pinnacle Industries and **VDL Groep**, of Eindhoven, Netherlands, partnered in August 2016 to establish **VDL Pinnacle Engineering India** in Pune, India. The joint venture will provide specialized engineering services for the production automation industry worldwide, focusing primarily on body-in-white (BIW) weld shops. With this collaboration, the company will provide services in process engineering, tool design, robot simulation, layouts and facilities engineering.

VDL Pinnacle Engineering India will supply optimized turn-key solutions according to the requirements of the Indian automotive OEMs and their Tier 1 partners. It also will provide

Industry NEWS

solutions to **VDL Steelweld**, a Dutch company that has several automotive customers in Europe, the U.S. and China.

In addition, VDL Pinnacle Engineering India will provide engineering services in product design for other VDL Groep companies such as the VDL Bus & Coach companies.

“We are delighted to partner with the VDL Groep, which is one of the most prominent and reputed family owned industrial groups of Europe,” said Sudhir Mehta, Chairman and Managing Director, Pinnacle Industries and Chairman Confederation of Indian Industry (CII), Western Region, speaking about the joint venture. “VDL brings the best-in-class technology coupled with their extremely strong network of 87 operating companies across Europe.”

The collaboration aims to become a preferred partner to the Indian automotive industry and also within VDL Groep in the near future. This is the first joint venture in India for the VDL Groep and marks their entrance into the expanding Indian automotive market.

“Our joint venture with Pinnacle marks our first foray into the fast-growing Indian automotive space,” Theo Toussaint, Executive Vice President and Member of the Executive Board, VDL Groep, said. “Our strong technical abilities, coupled with the highly skilled engineering resources available in India, will support not only our business for the Indian automotive OEMs, but also the worldwide operations of VDL Groep.”



Joint venture VDL Pinnacle Engineering India will provide specialized engineering services for the production automation industry worldwide, focusing primarily on body-in-white (BIW) weld shops.



Mahindra & Mahindra's DiGiSENSE is a smart application to empower its customers to digitally build knowledge 24x7 about the performance and location of their mobility products and tractors.

Mahindra connects vehicles via cloud-based technology platform

Mahindra & Mahindra Ltd (M&M Ltd) has launched DiGiSENSE, a technology solution that connects Mahindra vehicles, tractors, trucks and construction equipment to the cloud. The company expects the open-architecture platform to greatly enhance the vehicle ownership experience by providing data 24x7 about the performance and location of their vehicles and by automatically upgrading the platform to the latest version on a periodic basis.

DiGiSENSE, which stands for digitally enabled sensing, will be available across Mahindra's range of mobility products from commercial and passenger vehicles to tractors and construction equipment. According to M&M, the DiGiSENSE launch makes the company the first OEM in India to integrate its product line-up onto a cloud-based technology platform.

The solution empowers owners, fleet operators, drivers, dealers and service teams to access vital information about their vehicles, trucks, tractors or construction equipment on a real-time basis from the driver's seat or remotely. Key features include route planning and delivery tracking, vehicle utilization reports, trip optimization, alerts and machine-hour operations and geofencing.

“Digitization is emerging as a key differentiator for business transformation, and connected vehicle technology is one such manifestation,” said Dr. Pawan

Goenka, Executive Director, Mahindra & Mahindra, at the launch of DiGiSENSE. “At Mahindra, we regularly challenge conventional thinking and create disruptions and the launch of DiGiSENSE 1.0 is one such effort to adopt technology to develop new ecosystems. It is the first-of-its-kind technology platform which is multi-application and multi-product enabled. From providing real-time data, to tracking performance and productivity of the vehicles, DiGiSENSE will enable customers to control their businesses.”

The cloud-based technology platform will allow customers to digitally build knowledge 24x7 about the performance and location of their vehicles. Drivers can contact emergency breakdown services or pull up a route planner at the touch of a button, fleet owners and dealers can track the location of their vehicles in real time, while remote diagnostics and reports allow service teams to monitor the vehicle's health and productivity parameters, on a real-time basis.

DiGiSENSE will initially be available in the Jeeto and Imperio in the small commercial vehicles market, the Arjun Novo in the tractor market, the Mahindra Blazo in the heavy commercial vehicles market, and the Earthmaster in the construction equipment market. Available as a subscription-based service, DiGiSENSE will eventually be available across Mahindra's entire vehicle lineup, says M&M.

AUTOMOTIVE POWERTRAINS | PROPULSION

Nissan unveils variable-compression-ratio ICE for 2018 Infiniti production model

Nissan broke new ground for gasoline engines at the 2016 Paris Motor Show when it unveiled the first production-intent variable-compression-ratio gasoline engine. The VC-Turbo, a 2.0-L inline four cylinder designed in house, features a novel cranktrain and control system that enables the effective compression ratio to be varied between 8.0:1 and 14:1, depending on load.

Making its debut under the automaker's Infiniti brand, the VC-Turbo (VC-T) has been designed to replace the company's 3.5-L V6, with a target output of 268 hp (200 kW) and 288 lb·ft (390 N·m). Using two fuel-injection systems, Infiniti has set a target for fuel consumption reduction of 27% compared with the V6. The engine is being readied for series production in early 2018. The initial vehicle application is the new QX50 crossover.

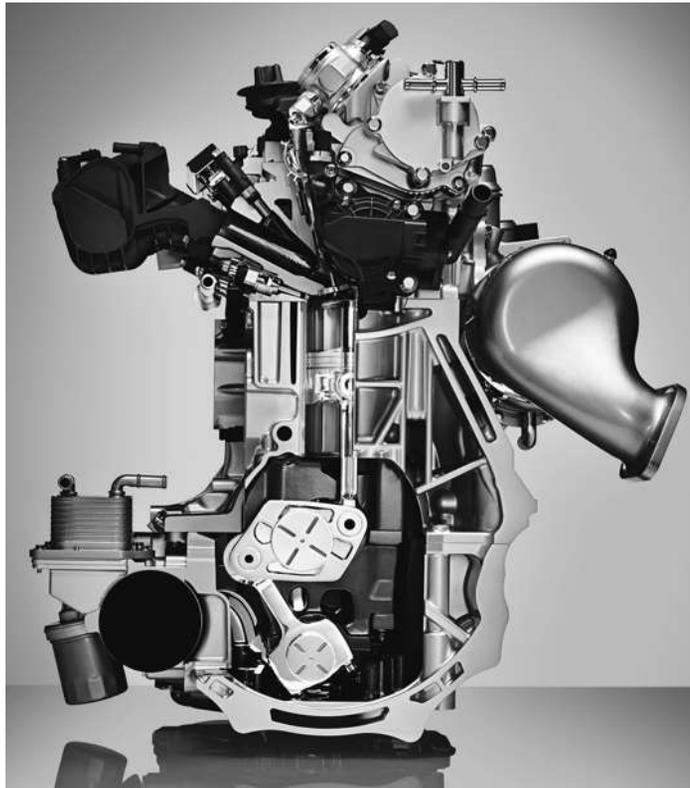
Visit this link to see Nissan's U.S. patent application: <http://pdfaiw.uspto.gov/.aiw?PageNum=0&docid=20130327302>

'Harmonic Drive' system

Typically, VCR engines alter the compression ratio by raising or lowering the height of the piston at top dead center, but the Infiniti engine achieves this in a unique fashion. Nissan engineers have adopted a multi-link system with an electric motor actuator, with what they describe as "Harmonic Drive reduction gear."

The electric motor drives the reduction gear, which moves an angled actuator arm. The arm in turn rotates a control shaft with four aligned eccentric cams, one for each cylinder. An intermediate link with bearings at each end connects the eccentric cam at the bottom end to the multi-link at the top end. The center of the multi-link runs in a bearing around the crankshaft journal.

A second bearing on the multilink, positioned 180° degrees from that connecting the intermediate link effectively serves as the piston connecting rod big-end bearing. This arrangement pro-



The 197-hp Nissan VC-Turbo engine is designed to replace the company's 3.5-L V6, first in Infiniti's QX50, while reducing weight by 25 kg and targeting fuel consumption reductions of 27% vs. the V6.

duces a 17° offset of the conrod from the crankshaft journal center point.

The Harmonic Drive is controlled by a dedicated ECU which gathers data from engine sensors to determine the compression ratio required for given driving (load) conditions. Since a low compression ratio is desirable when power is required and a high compression ratio when efficiency is preferable, the piston height at TDC can be continuously varied as required by rotating the Harmonic Drive, which will determine the position of the multilink and hence the height of the piston in the cylinder bore.

See this Nissan video of the VC-T's operation: <https://www.youtube.com/watch?v=3rn-gZNBUI>

Outperforms the 3.5-L V6

As with other VCR engines, complexity, mass and cost are greater than in a conventional 4-cylinder gasoline engine.

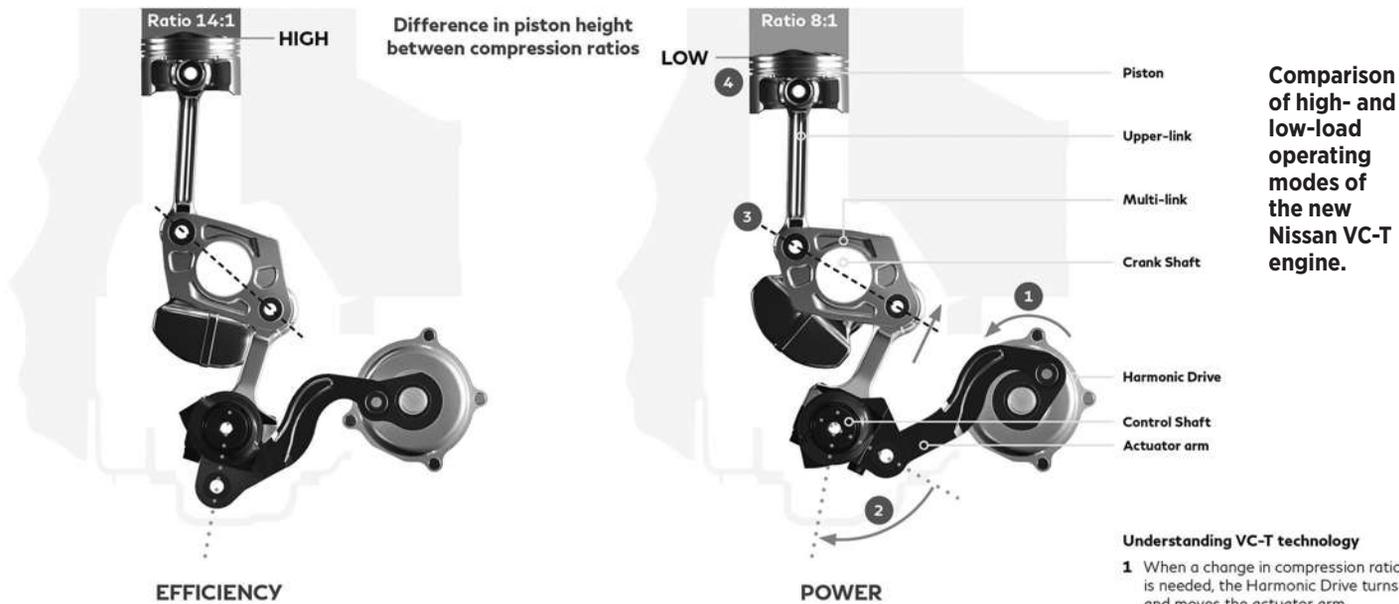
"Instead of one conrod (for each cylinder), we have three," noted Alain Raposo, Global Vice-President Powertrain and EV Engineering for the Renault-Nissan Alliance at the engine's debut.

Raposo admitted that while the VC-T is more expensive to build than a conventional 4-cylinder turbocharged gasoline engine, it is also "cheaper, lighter and performance is also better" than the 3.5-L V6 it is designed to replace. The VC-T engine is around 25 kg (55 lb) lighter than the V6, according to Infiniti. The linerless cylinder block and head are aluminum and the multi-link cranktrain components are high-carbon steel alloy.

The motion described by the piston conrod big end is not circular as in a conventional engine's big-end bearing, it is more elliptical, with the conrod not passing through the vertical axis between the big and small end bearings. During the power stroke, the conrod remains more or less vertical: this reduces the side force on the piston and helps to reduce vibration.

TECHNOLOGY

Report



Raposo claims the engine produces 33% less vibration than generated by a conventional gasoline I4 and no balance shaft is required. There is more pressure on some bearings, he admits, but the pressure is similar to the pressures acting on diesel engine bearings, he explained.

Reduced side force on the reciprocating

components in the cylinder during operation results in lower friction between ring and bore, Raposo claims. Nissan's development team specified plasma-jet-coated bores that are hardened and honed to produce a low friction surface. The company claims a 44% reduction in cylinder friction as a result and no cylinder liners are required.

Two fuel injection systems

The development team addressed the fueling needs generated by the range of compression ratios by fitting both multi-point injection (MPI) for low compression and direct injection (GDI) for high-compression operation. Since GDI engines inherently generate higher particulate emissions, the continual phasing between GDI and MPI helps to contain particulates, Raposo noted. Both sets of injectors are brought into use under high load and high-rpm conditions.

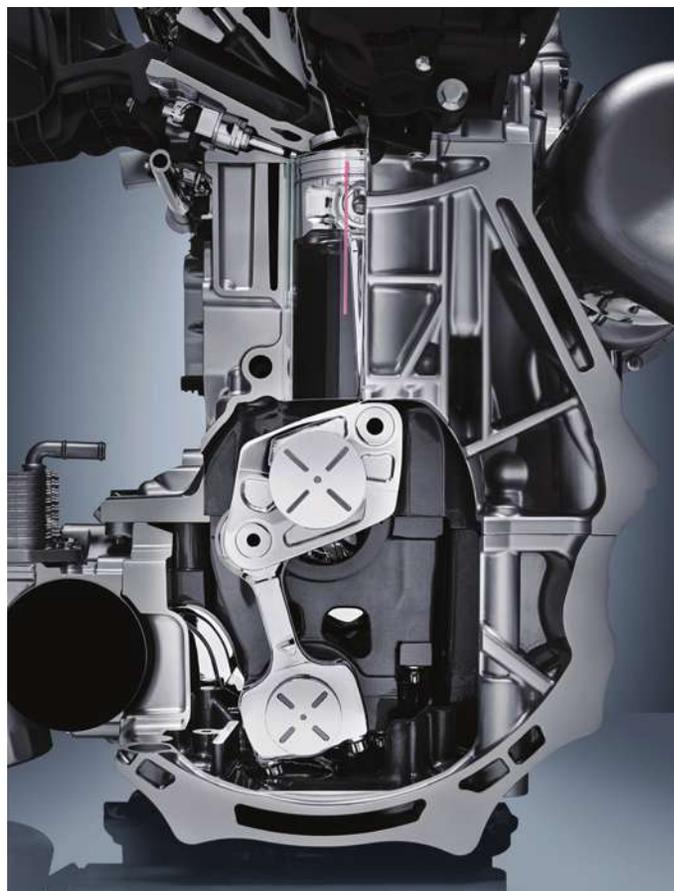
Both the inlet and exhaust camshafts are fitted with variable valve timing—electronically controlled on the inlet side and hydraulically actuated on the exhaust side.

Forced induction is provided by a single-scroll turbocharger equipped with an electronic wastegate actuator. The variable-compression system results in a variable displacement between 1.97-L and 1.997-L.

The VC-T engine development process was highly iterative. Engineers tested more than 100 prototype engines, covering the equivalent of more than 3 million km (nearly 1.9 million miles) of road testing and 30,000 h on test beds.

The new engine currently is in final development and on-road testing.

John Kendall



Piston height is altered by rotating the lower shaft, which changes the position of the multi-link connected to the piston conrod.

AUTOMOTIVE POWERTRAINS | PROPULSION

Inside Porsche's new V8 and V6 powertrains

Porsche broke a “golden rule” of automotive engineering when it began development of the second generation Panamera: Never develop a new car, a new powertrain and a new factory simultaneously. So confessed Dr. Manfred Harrer, Vice President of Chassis Development.

But despite the transgression, the resulting technologies lift the latest Panamera into a new dimension of sedan capabilities, as previously reported (<http://articles.sae.org/14896/>). We now have full details of its powertrain, plus experience of how the most powerful, twin-scroll gasoline V8 performs on track.

Panamera owners who favor track-day activities will discover, as the author did, that 0-100 km/h acceleration comes in 3.4 s with the optional SportPlus via Launch Control. And they'll find that pulling 1.5 g in tight corners, as we did on the Lausitzring EuroSpeedway near Dresden, is no problem. Owners also should rest assured that the new Panamera has been extensively tested on the Nürburgring-Nordschleife circuit, achieving a lap time of 7 min 38 s, 14 s quicker than the previous-generation Panamera.

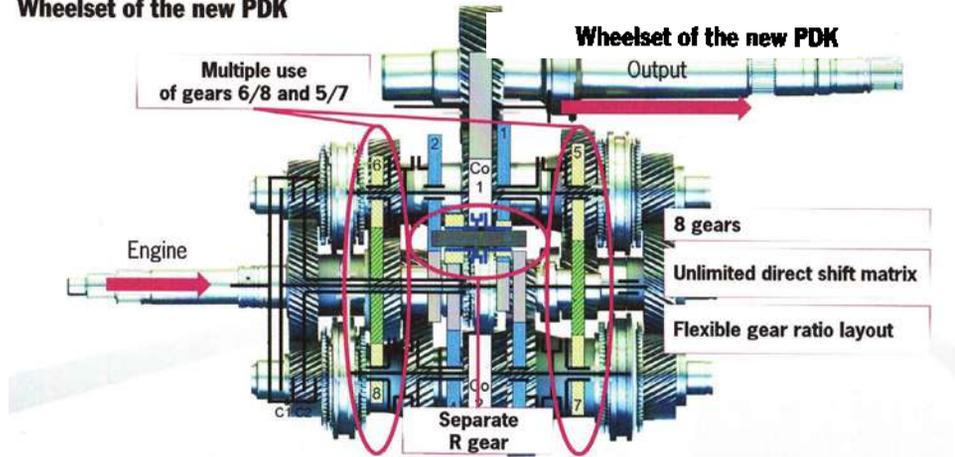
More hp/L, another gear for PDK

There are two new V8 and V6 gasoline units and a new Audi-sourced V8 diesel. An 8-speed PDK twin-clutch designed



Porsche's new high-torque, bi-turbo 398-hp gasoline V8 goes into the Panamera before it sees duty in other VW Group applications; note twin turbochargers located in the vee of the cylinder block. The engine features cylinder deactivation and a new type of cylinder-bore coating.

Wheelset of the new PDK



Wheelset detail of the new PDK gearbox for the Porsche Panamera.

and developed by Porsche and built by ZF, replaces a 7-speed. In order to leverage scale within the VW Group, the new gas engines are expected to see future use in Audis, Bentleys, and potentially even a Lamborghini.

Criteria for the new engine lineup, as listed by Dr. Thomas Günther, Director of Powertrain, will not surprise SAE readers. The list includes lower fuel consumption and emissions; reduced weight; more efficient packaging; enhanced performance and that essential for all Porsches—the “right” aural signature. Modularity, to facilitate the flexibility demanded for hybrid variants, was also essential.

The Panamera's “halo” power unit is a new 4.0-L DOHC V8 with two twin-scroll turbochargers delivering a torque plateau rather than a curve: 770 N·m (568 lb-ft) from 1960 to 4500 rpm. Zero to 200 km/h (124 mph) takes a best 12.7 s. Fuel consumption for this version shows a 1.1-L/100-km improvement to a best 9.3 L/100 km and 212 g/km CO₂ emissions. Claimed specific power is 137.5 hp/L versus 108.3 hp/L for the outgoing 4.8-L V8.

The longitudinally-mounted engine's aluminum cylinder block is made using what Porsche engineers describe as “a special sand cast process.” The block weighs 39.1 kg (86 lb), a 6.7 kg (14.7 lb) reduction of mass versus the 4.8-L.

A new development of iron coating on the cylinder linings is used. Engineers describe it as being very highly wear-resistant and durable.

Wear is reduced by about a tenth at the motion reversal point of the piston rings, which have a chrome nitride coating. This should help with the high load changes generated by hybrid versions. An atmospheric plasma spray method is used to give a coating layer of 150 microns.

Mass reduction actions are evident throughout the block and include a crankshaft drive weight that weighs 1.4 kg (3 lb) less and uses an intermediate shaft to drive the water pump and timing drive. The switchable water pump has a toothed gear drive inside the engine which improves power unit



The VarioCam Plus system controls cylinder deactivation in Porsche's new V8.

TECHNOLOGY Report

packaging. Best weight reduction for the new V8 engines is 9.5 kg for the gasoline unit.

Packaging was also aided by a central turbo configuration, said Günther. The twin-scroll turbochargers, with counter-rotating turbines, have a maximum charge pressure of 0.3 bar (4.3 psi). Compact, isolated exhaust manifolds are fitted. Process air for the chargers is configured as a dual-branch system. It passes through intercoolers on each side of the engine, through one throttle valve on each side and into the left and right cylinder banks.

Fuel injectors are placed centrally in the combustion chamber. Fuel pressure is 250 bar (3626 psi) compared to the old engine's 140-bar (2030-psi) injection system. The injectors have seven nozzles and each cylinder bank gets a high pressure pump.

Low friction lubricants are used throughout the engine. Oil consumption is said to have been reduced by up to 50%.

Broad-bandwidth cylinder deactivation

For high-*g* driving enthusiasts the new Panamera's oil circulation gets a lot of attention. Oil passages are partitioned into the oil supply for the engine and for the cylinder head. A fully variable vane oil pump is fitted with a valve controlling map-specific figures. An electronic switching valve located centrally in the V of the block controls piston spray nozzles. Churning losses are reduced and oil circulation volume controlled.

The Turbo has cylinder deactivation capability, a system increasingly used within VW Group. In 4-cylinder phases, fuel economy can be improved by up to 30%. Deactivation and reactivation of the cylinder is via Porsche's VarioCam Plus, using a 2-stage sliding cam system. Under suitable load conditions, cylinder deactivation is available from 950 rpm to 3500 rpm with a 250-N·m (184 lb-ft) torque limit.

It is 30 years since Porsche introduced a twin-clutch transmission (PDK) into its race cars and into production models in 2008. The new PDK allows the car to achieve top



Convincing on track, the new 4.0-L 398-hp engine, 306 km/h-capable Porsche Panamera Turbo demonstrated 1.5-*g* capability with the author behind the wheel.

speed in 6th, with the added two ratios providing overdrive. There is an 11.17 ratio spread against 10.2 spread with the previous 7-speed. The gearbox remains compact—in fact its “internals” are 142-mm (5.6-in) shorter than the 7-speed. It brings a claimed 1.4% fuel economy gain.

New 8-speed PDK and V8 diesel

We asked Michael Funk, PDK Project Manager, about the decision to plump for an 8-speeder not a nine. He replied, “It’s right for us”—keeping in sync with the Panamera’s combination of performance and comfort.

Sourced from ZF, the PDK is package-protected for hybridization. It uses racecar-derived spray lubrication via a demand-based variable vane oil pump, claimed as a “first” for a road car. The gearbox uses a new oil, developed to reduce friction losses; full details were not yet released when this article was written.

Net weight reduction for the complete powertrain of the Panamera Turbo is 2.5 kg (5.5 lb), the 8-speed gearbox adding 7 kg (15.4 lb) compared to the 7-speed.

The newly developed 4.0-L V8 diesel is sourced from Audi but it has been tuned and adapted by Porsche. It replaces the previous Panamera’s 6-cylinder diesel and delivers 850 N·m (627 lb-ft) from 1000-3250 rpm—another broad plateau rather than a curve. It has a claimed output of 310 kW (415 hp). Similar to the gas V8, the diesel also has

a central dual turbocharger configuration but these are sequential. The peak torque at 1000 rpm is achieved with only one turbo engaged. Both turbos have variable-turbine geometry.

Sequential turbocharging is facilitated via variable valve timing of intake and exhaust valves. Axially sliding cam pieces on the camshaft are used to change switching positions, explained Dr. Günther. Electromagnetic actuators slide the cam pieces.

The diesel’s common rail system operates at 2500 bar (36,259 psi).

Best 0-100 km/h time with optional Sport Chrono Plus is 4.1 s; the 200 km/h dash takes 16.8 s. As an option, the car has a larger fuel tank of 90 L (23.9 gal) to provide 1475 km (916 mi) range potential.

V8 births a V6

The 2.9-L V6 makes the third Panamera power source and was designed in house by Porsche without VW involvement, engineers claim. It produces 324 kW (434 hp) at 5650 rpm and is rated at a claimed 550 N·m (406 lb-ft) from 1750-5500 rpm. Claimed performance figures include a best (with Sport Chrono package) 0-100-km/h time of 4.2 s.

The new V6 also has its two turbochargers tucked between the cylinder banks. The engine weighs 14 kg (31 lb) less than the previous car’s V6. Although similar in design to the V8 gasoline unit, the V6 has variable valve timing in both part- and high-load operation.

Stuart Birch

AUTOMOTIVE PROPULSION | FUELS

GM, Honda execs agree: Higher octane gas needed to optimize ICE efficiency

Raising the octane level of pump gasoline in the U.S. is integral to optimizing advanced combustion engines now in development, said GM and Honda executives at the 2016 CAR Management Briefing Seminars in Traverse City, MI. Their comments prompted positive but non-committal comments from Chris Grundler, Director of the Office of Transportation and Air Quality for the U.S. EPA.

During a panel discussion on future powertrains, Dan Nicholson, VP of Global Propulsion Systems at GM, and Robert Bienenfeld, Assistant VP of Environment and Energy Strategy at American Honda, agreed that the industry must push for a higher fuel-octane “floor” in the U.S.

“Higher octane fuels are the cheapest CO₂ reduction on a well-to-wheels analysis,” Nicholson told panel moderator Brett Smith of CAR. “Fuels and engines must be designed as a total system. It makes absolutely no sense to have fuel out of the mix” of engine-technology discussions, he asserted.

Nicholson added that higher-octane, purpose-designed fuels “can be delivered very cost effectively.” A U.S. Dept. of Energy analysis proved the benefit of higher octane levels in improving combustion efficiency and reducing engine-out CO₂, he said.

Honda’s Bienenfeld pointed out the benefits of higher fuel octane levels on advanced turbocharged engines operating under high-load conditions and in



Robert Bienenfeld of Honda (left) and GM’s Dan Nicholson are on the same page regarding the engine-efficiency benefits of higher octane fuel. (Lindsay Brooke photos)

large-vehicle applications. He noted that boosted gasoline engines, hybrids and fuel-cell vehicles are on the future-development path at Honda. Nicholson touted the trend toward higher Otto-cycle compression ratios and said his engineering teams are looking at Miller cycle combustion, in conjunction with turbocharging, “earning its way into the portfolio.”

Nicholson also said he’s bullish on diesels in the U.S., “which is one of the few growth markets” for compression-ignition engines, he stated.

Regarding 48-volt hybrids, Honda considers them to be cost effective “if the [current] standards stop at 2025,” Bienenfeld said.

EPA’s Grundler, speaking at MBS later in the day, noted that his agency is participating in the U.S. Dept. of Energy’s Optima project studying future fuels and

has a working group focused on gasoline octane. “Fuel changes are not part of the TAR [Technology Assessment Report, part of the Mid-term Review of the current CAFE regulations],” he said, while suggesting that higher octane levels be considered for after 2025 “as long as increasing octane levels do not increase greenhouse-gas emissions.”

The Optima project aims at developing co-optimized fuels with a range of new engines for light-, medium-, and heavy vehicle use. Announced at the SAE High-Efficiency Engines Symposium by Dr. Wagner, Director of the Fuels, Engines, and Emissions Research Center at Oak Ridge National Laboratory, Optima is targeting a 30% reduction in petroleum consumption, per vehicle, compared with a projected 2030 base case that uses today’s fuels. The initiative is a collaboration with producers of gasoline and ethanol and the auto industry.

If Optima achieves its goal, it could reduce petroleum consumption by 4.5 billion barrels and save consumers up to \$50 billion, according to the DoE.

Raising the U.S. octane “floor” will be essential for new combustion strategies currently in development for the 2020s including advanced Miller cycle and those combining lean-burn and stoichiometric operation aimed at achieving peak efficiency levels of 50% and above. ORNL’s Dr. Wagner told the SAE audience that some multi-cylinder dyno engines have pushed beyond 55%.

Mazda’s Skyactiv program is progressing through G1, G2, and G3 development stages toward a marriage of Otto and Diesel cycle characteristics. Engineers’ target for the G3 is 18:1 compression ratio at lambda 2.5—a 40% improvement in thermal efficiency by setting the ideal pressure and temperature for homogeneous charge compression ignition (HCCI).

In Europe, the 102-RON (research octane number) “super premium” gasoline that’s widely available helps deliver a 10% increase in fuel efficiency for engines running compression ratios above 11.5:1, compared with engines running 9.0 to 9.5:1 using the 95-RON fuel that’s marketed as the mid-grade gas in Europe.

Lindsay Brooke



Fuels industry already trial-ballooning a high-octane future? Price differential between regular- and premium-unleaded gasoline earlier this year in one part of the USA nearly \$1 per gallon; a 20-cent difference was the longtime norm. (Bill Visnic)

AUTOMOTIVE POWERTRAINS | PROPULSION

Optimizing engine oil warm-up strategies for 'real-world' driving

Optimizing engines for the new era of 'real-world' driving cycles will require new lubrication strategies—fast warm-up being a particular area of focus. A recent U.K. government survey showed that the average car journey time has fallen to only 22 minutes and average distance to 12 km (7.5 m), most of it in urban areas. And such extreme duty cycles are increasingly typical in other global regions. They emphasize rapid warm-up for reducing emissions and fuel consumption, faster cabin heating and reduced maintenance.

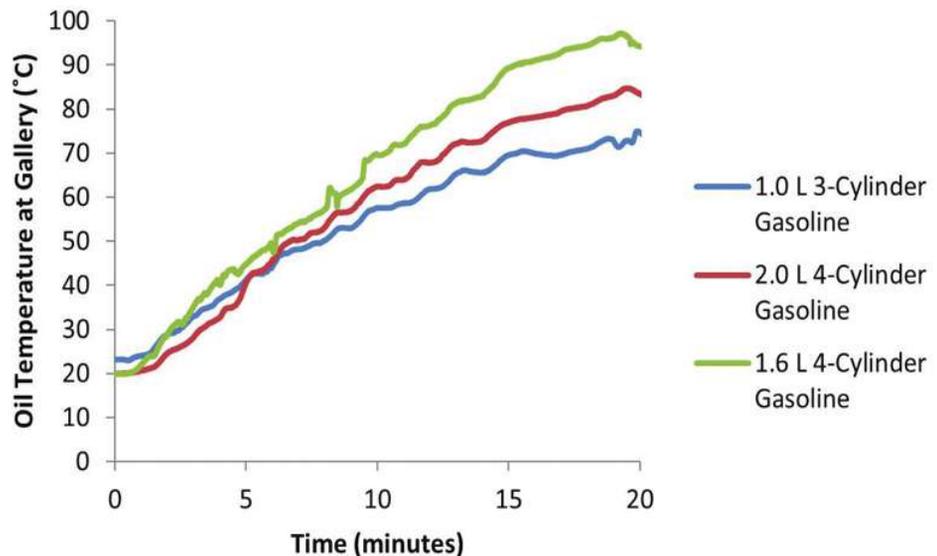
But the contribution to warm-up time due to heating the oil within the engine is often under-estimated, experts note.

"The specific thermal capacity of oil surprises many people because it's substantially higher than for the metals used for the high-mass engine components," said Oliver Taylor, a chief engineer at **BP Castrol**. "Saving three liters (approximately 2.6 kg/5.7 lb) of oil is equivalent to shedding 6.4 kg (14 lb) from an aluminum block, or nearly 12 kg (26.5 lb) from an iron block. With that perspective, it becomes very clear how reducing the lubricant volume helps an engine to warm up more quickly."

Less oil in the sump

High levels of internal friction during cold-start conditions are the dominant reason for increased fuel consumption and emissions during warm-up, which can comprise a significant proportion of the average journey. Taylor explained that in Europe's new World Harmonized Light Vehicle Test Procedure (WLTP), up to 20% of the fuel energy is lost into warming the metal parts, coolant and oil of a typical current-generation engine.

That engine's oil volume throughout that time has to be sufficient to cater for the extremes required by a number of factors. In addition to that actually required for steady-state lubrication (i.e., the oil gallery requirement), the sump must contain sufficient lubricant to accommodate operation at a typical inclination of up to 30° from vertical, to allow de-aeration when the engine is working at maximum speeds for pro-



The importance of warm-up time: BP Castrol Nexcel chart showing test results from simulated WLTP cycles using three European engines.

longed periods and to achieve increasingly long oil-change intervals.

Another challenge comes from the increasingly complex lubricant additives required by today's significantly downsized boosted engines. Additives "push up the viscosity, imposing a limit on viscosity reduction, however thin the base oil," said Taylor. He told *Automotive Engineering* that electronic control of sump-oil volume can remove the need to always heat the full capacity required to accommodate the outer limits of these requirements.

BP Castrol testing shows that on a 2.0-L, highly-boosted, direct-injection gasoline engine, more than two liters of oil can be removed from the engine lubrication circuit—effectively reducing the parasitic drag, or windage, that results from sump oil splashing on the cranktrain during operation. The reduction can significantly improve emissions and fuel consumption during most journeys.

Containing the oil within what Taylor terms an "intelligent cell"—remote from the engine—also permits new approaches to the management of vital additives included within the oil formulation. One such approach is BP Castrol's self-contained, electronically managed sealed-cell system called Nexcel; it is installed via a docking system (<http://articles.sae.org/14426/>) and

can be changed within 90 s, according to Taylor, who led its development.

Governing the oil-additive content

The concept of a sealed-cell, easily changed engine oil module is increasingly viable within the complex issue of thermal management during warm-up, Taylor argues. He and colleagues presented results of an investigation into the effect of oil warm-up on CO₂ emissions in a 2016 **SAE** Technical Paper (<http://papers.sae.org/2016-01-0892/>).

Nexcel has the capability to operate in a dry-sump architecture, but it can also be applied to a wet-sump installation, he explained. The system maintains sufficient oil in the engine's oil pan to ensure adequate coverage of the oil pick-up, but retains the surplus within the cell. This "substantially reduces the thermal capacity of the oil circulating in the engine," he said.

Contemporary engine oils contain up to 15% additives by weight, enabling them to remain effective for the extended oil-change intervals required by OEMs. But the additives' high viscosity contradicts the use of low-viscosity base stock to reduce engine friction. Taylor explained that the Nexcel unit "can be arranged to govern the additive system, allowing the



Self-contained Nexcel oil module being installed in an Aston Martin. The sealed-cell concept also is being investigated for medium- and heavy-duty trucks and equipment in addition to light-duty passenger vehicles.

engine to be supplied with oil containing 'tailored' additive content.

"That makes advanced oils a very attractive, low-cost route to reducing friction," he said.

So far, BP Castrol is keeping secret details of the technique, but Taylor indicated that it is related to a new technology the company is developing based on "unique new chemistries" to actively control lubricant quality over the oil drain interval. "These techniques together will allow a precise and stable composition of the lubricant throughout the change interval," claimed Taylor. He believes this is one of the major factors that will enable a significant further step toward highly optimized, vehicle-specific oils.

"Because the closed nature of the Nexcel system ensures the engine always receives the oil specified by engine designers, they can extend the envelope of possibilities in areas like bearing loads and temperatures while retaining robust durability margins," Taylor said. "Add the ability to manage oil quality through the change interval and you have a very powerful new tool for enabling new generations of downsized, highly-efficient engines."

Oil-recycling benefit

The complexity and care needed to efficiently collect and manage the various oil grades drained from vehicles means that the vast majority of used oil becomes contaminated by other grades, or even by completely different fluids. This makes it impractical to re-refine, leading to a high proportion of recovered auto lubricants being used as fuel for heating-system burners that are "often of poor efficiency and questionable" overall environmental performance, noted BP Castrol Sustainability Director John Ward-Zinski.

"The benefit of controlling the feedstock for re-refining will be very significant," he explained, noting that just one-half liter of lubricant can be produced from 42 L of crude oil. BP's research suggests 34 L of lubricant can be extracted from 42 L of recycled oil — "but only if you eliminate cross-contamination during the recycling process," Ward-Zinski said.

The sealed-cell system enables this "because it keeps individual oil types protected within their cells up to the point of re-refining."

Stuart Birch

OFF-HIGHWAY HEAVY-DUTY POWERTRAIN

Eaton demonstrates waste heat recovery, variable valve actuation for HD diesels

Eaton demonstrated a range of waste heat recovery (WHR) technologies for heavy-duty diesel engines at the IAA Commercial Vehicles show in Hanover, Germany, as well as variable valve timing systems, highlighting their potential to reduce fuel consumption and help reduce emissions.

Both indirect and direct WHR systems were on display. The organic Rankine cycle (ORC) design recovers waste heat indirectly using a heat exchanger with the exhaust system. Alternatively, Eaton's "electrified" system recovers energy directly using an exhaust-driven Roots compressor in conjunction with a motor/generator.

ORC WHR systems can yield fuel-economy improvements of around 5%, but system cost is high, involving a small external combustion piston engine. Eaton looked at what fluids were already carried on board the vehicle to avoid adding another for the ORC WHR system. The first fluid the company considered was ethylene glycol, already used in engine coolant systems.

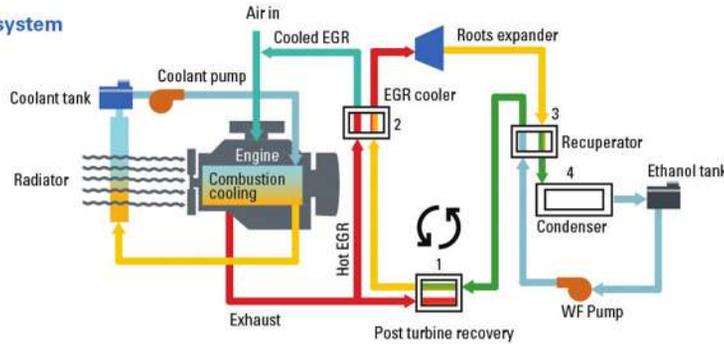
As Larry Bennett, director of advanced engineering, Eaton Vehicle Group, observes, the fluid would already be hot from use as an engine coolant, but would it have the potential to add more exhaust heat to it and extract more energy? "Now we can create most of the ORC system with existing componentry," said Bennett. "We now have a U.S. Department of Energy (DOE) grant. We're working with Paccar, Shell Oil and Mississippi State University, which is where all the actual testing will take place.

"Shell is working on a fluid that has the capability to do this for us. The idea is to see if we can achieve enough waste heat and form this face transition, then utilize it and see if it's going to work."

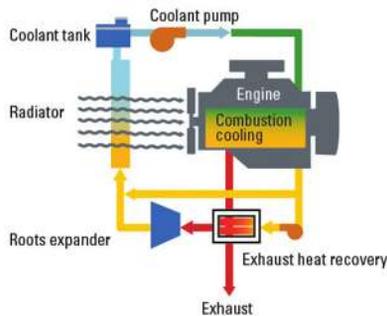
One of Eaton's research scientists suggested that diesel exhaust fluid (DEF)/AdBlue urea solution for exhaust

TECHNOLOGY Report

Conventional WHR system



Affordable rankine cycle technology



A Roots-type compressor combined with an electric motor/generator could offer a range of waste heat recovery functions.

Eaton's affordable Rankine cycle could bring fuel-economy improvements of around 5%.



A compression engine brake in diesel engines is possible by introducing variable valve actuation.

aftertreatment of oxides of nitrogen (NOx) would be an ideal ORC fluid.

"The idea is exactly the same—you perform the Rankine cycle by boiling the DEF fluid," explained Bennett. "One of the interesting byproducts is that after you heat it up, ammonia gas comes off and when you cool it down, it doesn't want to readily return to the liquid state. We can store that ammonia gas."

Once the engine has cooled down and is restarted, NOx output and treatment is an issue. "If you start it back up, you're producing a ton of NOx because you don't have ammonia gas to be able to treat it," said Bennett. "You need the temperature in the exhaust system to get up to 250°C in order to take the liquid ammonia you're injecting to get it to vaporize so that you can treat the NOx."

The ammonia stored from the evaporated DEF should be enough to treat NOx for the first 15 minutes as the engine comes up to operating temperature. "It's all research, all modeling simulation, but it appears feasible," he said.

The direct WHR system involves fitting a Roots compressor system right next to the exhaust manifold and using the exhaust gas flow to drive the compressor rotors. Short-term testing shows that the energy can be recaptured.

"The initial concept is to have a motor/generator hooked up to it, then basically take the energy and put it in a battery," said Bennett. This is not the most efficient way to recapture energy, but it offers another possibility. Eaton's research scientists believe that this system could be used as a pump when there is a need for high rates of exhaust gas recirculation (EGR). The system could potentially deliver high rates of

EGR independent of engine speed.

Eaton had previously developed an electronically assisted variable-speed supercharger for use with gasoline engines. "In this application, we can now vary, independent of engine speed, the amount of boost that the engine can get," Bennett explained. "On a diesel, that has a lot of advantages in the form of downsizing and instant torque. The big thing would be to manage airflow and exhaust flow independent of engine speed." That capability would be highly attractive to engine manufacturers.

The direct WHR system has shown through simulation a 22% improvement in fuel economy while reducing NOx, Eaton claims.

Variable valve actuation has not been widely used so far with diesel engines, but there are a number of potential advantages. The first is a compression engine brake. Early intake valve closing and late intake valve closing could reduce combustion temperatures and NOx, or improve efficiency.

"You could have early exhaust valve closing for a transient to give faster boost in a turbocharger," said Majo Ceur, engineering manager, advanced valvetrain, Eaton Vehicle Group. "You could de-activate cylinders in light load conditions so that you could have better fuel efficiency."

Eaton is investigating valve-operation designs that would enable a range of such functions.

John Kendall

AUTOMOTIVE CHASSIS

Mazda's 2017 G-Vectoring Control brings dynamic refinement



Co-developed with Hitachi Automotive and the Kanagawa Institute of Technology, Mazda's GVC monitors the speed of steering-wheel inputs then signals the engine to reduce torque to a minute degree. The resulting deceleration, nearly imperceptible to the driver, delicately loads the front axle and thus tightens up compliance in the car's steering and front suspension.

Spend time with Mazda's talented vehicle-dynamics engineers as they fine-tune a new model before production release and you may hear the Japanese term *jinba ittai*—the concept of driver and car (more literally, horse and rider) as one. And that concept was very much at play during development of the automaker's latest technology for improving steering response, smoothness and precision.

It's called G-Vectoring Control (GVC), a name that is a bit of a misnomer. It is not a torque-vectoring system aimed at dramatically improving race-circuit lap times. Rather, the purpose of the system is to endow the vehicle with refined and natural smoothness in normal day-to-day driving environments.

To hear Daisuke Umetsu, Mazda's 35-year-old development leader explain it, "Longitudinal acceleration is modulated in response to lateral jerk for harmonious *g* transition. The GVC control applies minute, almost imperceptible longitude deceleration, less than 0.05 *g*—far less than normal engine braking—sensing two input sources: steering input angle and vehicle velocity." He says the resulting system, standard on the 2017 Mazda3 (Axela in Japan) and Mazda6 (Atenza) and expected to spread to other models, is designed to provide "peace of mind."

Controller integrated with PC

A simpler explanation is that GVC, co-developed with Hitachi Automotive

and Kanagawa Institute of Technology, closely monitors the speed of steering-wheel inputs then signals the engine to reduce torque to a minute degree. The resulting deceleration, hardly perceptible to the driver and without drama, delicately loads the front axle and thus tightens up compliance in the car's steering and front suspension.

Umetsu likens the function to that of the top expert drivers, citing the example of the legendary Yoshimi Katayama, who drove various Mazda works racing cars at Le Mans and elsewhere. Turning into a bend or curve, Katayama would have smoothly increased vertical force up front, through steady-state, to accelerating with vertical force shifting rearward.

Developed over a nearly eight-year period, GVC performs the expert-like function seamlessly and smoothly while using the engine as "the actuator, with no additional hardware required," Umetsu explained to *Automotive Engineering* during a technical presentation and ride-and-drive event earlier this year. He noted that the GVC controller is integrated within the powertrain control module (PCM), occupying a scant 3-kB in Mazda's 3-MB passenger car PCM.

Mazda dispatched a development team to Europe with the GVC-equipped Mazda6 prototype to obtain subjective responses and evaluations on public roads including high-speed motorways in the hands of 20 drivers of different nationalities and vary-

ing driving skills. Reactions were most positive, noted Umetsu.

Unique development team

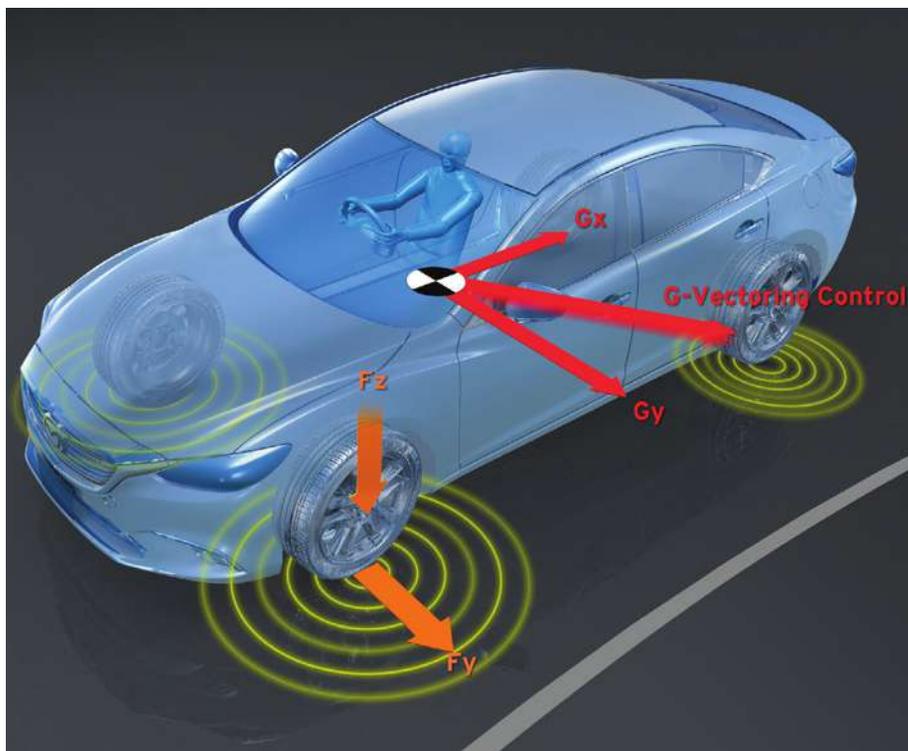
The cross-functional GVC team of about 40 members is an interesting and unique joint R&D entity of OEM, supplier and academic engineers. There is no middle-management supervision, but the organization has the full support of Mazda Chairman Seita Kanai, R&D head Kiyoshi Fujiwara and his predecessor, Hirotaka Kanazawa.

Umetsu, an-art-major-turned-neuroscience-graduate of the University of Tsukuba, joined Mazda in 2006. He is a senior specialist in the vehicle development department, responsible for chassis dynamics. Like the team's other members he does not specialize in GVC; his primary job function is a vehicle development engineer-driver. Umetsu has been involved in the development of such vehicles as the CX-5, the new MX-5 roadster and its near-twin Fiat 124 Spider, spending a year with the latter in Italy.

The initial proposal came from Hitachi, employing brakes for vehicle dynamics control with higher deceleration intervention. This ordinary approach was quickly abandoned. Umetsu's first encounter with the GVC concept was on the Tsukuba race circuit where he met Prof. Yamakado, at the time a Hitachi researcher specializing in engine control and fuel injection and a

TECHNOLOGY

Report



The GVC control applies almost imperceptible longitude deceleration, less than 0.05 g —far less than normal engine braking—sensing two input sources: steering input angle and vehicle velocity.

fellow track-day enthusiast. Their meeting, and conversations with others at J-SAE events, spawned ideas that led to G-Vectoring Control.

Umetsu also attributes quantum leaps in powertrain control and chassis technologies. Included were learnings from development of the Mazda Demio (Mazda2) battery-electric vehicle that the company offered to selected lease customers. That car's brake- or electri-

cally-actuated deceleration was in the order of 0.1 to 0.3 g , versus the production GVC system's 0.05 g . But a key enabler is the Skyactiv engine family, both gasoline and diesel, that incorporates extremely high control precision and responsiveness.

Technical details of the G-Vectoring Control can be found in JSAE technical papers 20165248, 49, 50 (in Japanese).

Jack Yamaguchi

AUTOMOTIVE CHASSIS

Tenneco's predictive active ride control may doom the anti-roll bar by 2021

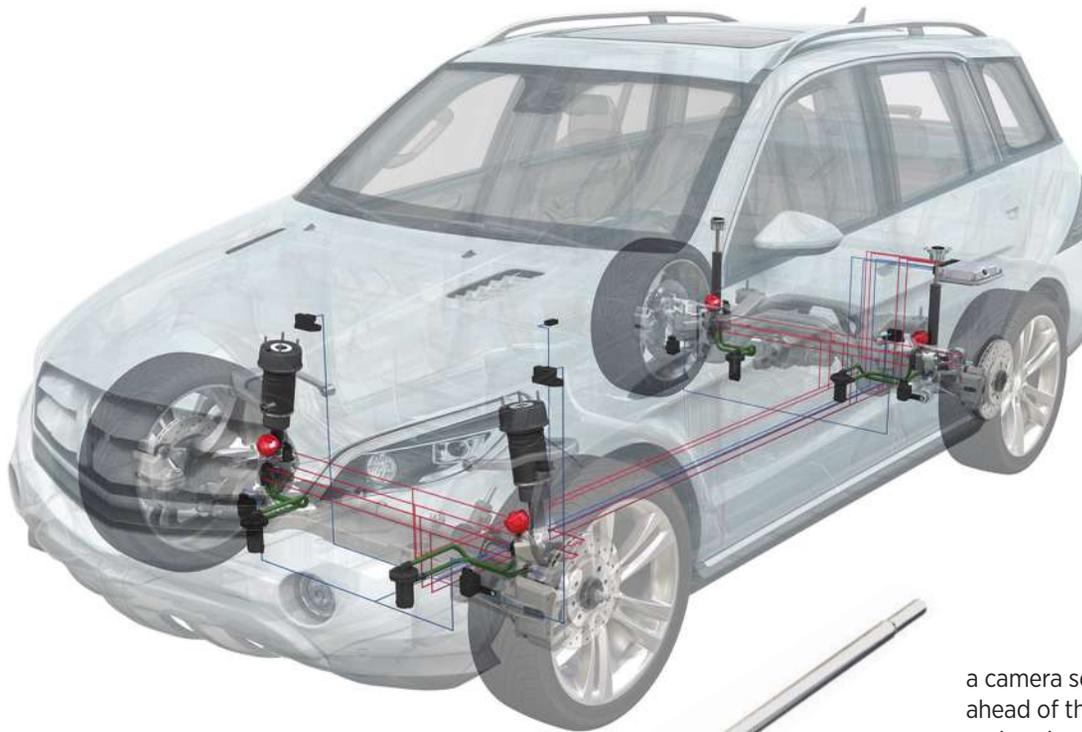
Are the anti-roll bar's days numbered? The answer is probably "yes" — at least for premium-model cars and light trucks, as advanced active ride control systems that use the vehicle's sensor array become more widely adopted. Tenneco, through its Monroe subsidiary, is currently developing a fully active suspension system with significant advances over incumbent semi-active systems.

Current production suspension systems typically rely on electronic actuation of the damper valves to improve damping response. In the case of the Monroe CVSA2 system, the dampers are equipped with two electronically activated valves to control both the rebound and compression strokes of the dampers. The aim is to improve ride and handling, particularly for luxury models, SUVs and sports cars.

A further development of the system, called CVSA2/Kinetic, can already eliminate the need for anti-roll bars by providing a hydraulic connection between the CVSA2 dampers on each axle. This provides improved ride comfort by providing control over vehicle roll. This system enables vehicle weight to be reduced by removing the anti-roll bars, but the level of ride control is still limited by the reliance on wheel movement to generate the damping forces.

Tenneco's latest ride-control system, ACOCAR, eliminates the need for anti-roll bars. There are two variants of the system under evaluation, as *Automotive Engineering* was shown during a recent demonstration in Europe. One has no interconnection between suspension dampers on the same axle. In this case, each damper is equipped with an integrated electrically powered pump, which continuously circulates oil through the shock absorber, with damping valves that can be controlled independently to control vehicle body movement.

The other ACOCAR system uses a single pump for each axle, providing pressure to each damper as required.



Monroe's ACOCAR system under development would provide independently acting dampers at each wheel able to deal far more effectively with speed bumps and potholes.



The ACOCAR damper system would incorporate a separate hydraulic pump at each wheel or on each axle. Predictive input could be provided from camera or laser sensors.

The result is a suspension that can react very rapidly to changes in surface quality. Our demonstration vehicle was a **Range Rover** equipped with ACOCAR. Part of the demo included driving with two wheels on smooth tarmac and the other two on a broken surface. Despite the significantly different surfaces the vehicle showed little deterioration in ride quality.

Cornering at speed also demonstrated the system's ability to contain roll. Roll angles were limited to a few degrees by the calibration, but the controlled wheel movements ensured tire/road contact to improve vehicle handling.

A production version of the ACOCAR

system is expected in the 2021-22 time-frame, according to Esteban Mendez, Tenneco Senior Research Engineer.

"The ACOCAR system has a much bigger impact on the total vehicle than the CVSA2 system," Mendez said. "The ACOCAR system requires much more from the OEM from an integration point of view. It requires a power source for the hydraulic pumps and it also requires full integration with the vehicle's ECU and everything around it."

The basic ACOCAR system is still a reactive setup, able to respond much more quickly to changes in surface and to control roll angles. Further improvements could be offered if the system incorporated other sensors. For example,

a camera scanning the road surface ahead of the vehicle would enable the system to anticipate factors affecting ride quality and prepare the damping system for them. Signals from such a camera system could be combined with existing cameras responsible for road sign recognition as well as scanning road markings and traffic lights.

If road scanning is added to the primary ride control, "you would be really able to pre-set the suspension at events like a speed bump or pothole to minimize the body motion even further, compared with what we are doing today," commented Gunther Bismans, Monroe's technical team leader for Vehicle Dynamics.

"Even in the case of potholes, if you know they are coming, you can keep the wheel up and prevent it from falling into the pothole to minimize the resulting impact," he explained, adding "I would expect a big improvement from such a system."

Other sensors, such as radar and laser based systems are also under evaluation. Camera-based systems would obviously not work effectively in low light conditions.

Tenneco engineers would not prescribe the sensor technology it is using, but would leave that choice to OEMs to decide which system they would prefer to offer. Testing with a range of sensors is being carried out to ensure that the system would work effectively regardless of the sensor system chosen.

John Kendall

AUTOMOTIVE CHASSIS

More details emerge of Citroën's new 'hydraulic cushion' suspension



Citroën is using a Cactus as a test vehicle for its "Advanced Comfort" development program.

First details are emerging of Citroën's new vehicle refinement package including an innovative suspension system, the existence of which was revealed by *Automotive Engineering* late last year; see <http://articles.sae.org/14498/>.

At that time, Citroën CEO Linda Jackson said of the still secret program: "The technology we are developing will deliver what I call the 'Citroën ride.'" Since then the Advanced Comfort Program has moved toward production. It uses secondary dampers that Citroën quaintly refers to as "hydraulic cushions" to complement the regular shock absorber and springs of each suspension unit.

The dampers work progressively, one for rebound, a second for compression, positioned at the upper and lower extremes of each unit instead of conventional bump stops. They should deliver better control throughout much of the suspension's travel.

The new suspension is designed to be cost effective and applicable across Citroën's model range. When it becomes available, possibly early 2017, it will mean au revoir to the relatively complex and expensive oléopneumatique systems that started with the ground-breaking 1955 DS and that are still used on some current versions of the C5.

Striving to reduce system cost

Citroën chassis engineers are refining the system on a Cactus test vehicle together with other complementary technologies to provide an integrated, holistic approach to smoother, quieter travel. More than 30 patents have been applied for, which means Citroën engineers are being a shade diffident about its design and development of the new system.

But what they are saying is that in instances of what it terms "slight compression and rebound," springs and shock absorbers work together to control vertical movement without need of the "cushions." But in "more significant" compression and rebound situations, springs and shock absorbers then work together with the "cushions" at suspension travel extremes gradually slowing movement, absorbing and dissipating energy, whereas typically, regular bump stops absorb energy suddenly and then partly return it.

Jackson said that if manufacturing costs can be met the new suspension's use will be extended across Citroën's car range, even to the little C1. This would mean the end of oléopneumatique. But it is not a standalone technology to smooth Citroën's future. Said Jackson: "Comfort is not just about suspension; it also encompasses seats, storage and the way you drive."

Going big on adhesive bonding

So when the suspension has completed its subtle damping, the bodyshell then enters the picture. Body stiffness figures have risen rapidly and hugely for almost all cars in recent years and Citroën believes that its use of structural bonding will take this further.

It is developing an "industrial process" specific to the company to bond structural parts using a discontinuous line of adhesive with an electrical weld point used only if the line is interrupted.

Citroën refers to "significantly greater overall body rigidity" being achieved – typically some 20%, a huge improvement over what is already in production and that should achieve a

very considerable reduction of vibration. There will also be cost and weight benefits, with the reduction in electrical welds required.

Seating is another complementary area to improve comfort. Comfortable seats have long been a Citroën forte but now memory foam, à la mattresses, are set to play a role, shaping to an individual passenger's body contours. Materials used include polyurethane foam and viscoelastic or textured foam.

The company has improved acoustic comfort and reduced vibration in recent models, including the latest C4 Picasso, which uses the PSA (Peugeot Citroën) Group's EMP2 platform, via damping of the front subframe and use of a dual-material acoustic shim for the rear suspension.

All of these development programs are incorporated in the test program Cactus. Depending on development program advances, including further patent applications, Citroën may release more information on its advanced comfort program in the near future, and some elements of the technologies will appear sooner rather than later.

Stuart Birch



It is known that secondary dampers which Citroën engineers call "hydraulic cushions" complement the regular shock absorber and springs of each suspension unit. The dampers work progressively, one for rebound, a second for compression, positioned at the upper and lower extremes of each a unit instead of conventional bump stops.

AUTOMOTIVE AUTONOMOUS TECHNOLOGY

JLR prepares to leave the road — autonomously

JaguarLandRover engineers are confident that when a driver of one of their future all-terrain autonomous vehicles wants to leave the pavement, technology will continue to provide guidance along gravel lanes or mountain trails, automatically checking ahead for anything from changing surfaces to overhead branches and threatening boulders.

And just as future V2V (vehicle to vehicle) communications capability will become available for autonomous on-road driving, it will also be available for off-road, constantly transmitting and updating warning information about obstacles and potential dangers to any following vehicles.

All this is part of a significant R&D program focused on off-road connected convoys. “In the future we will offer autonomous driving over any surface or terrain,” said JLR Product Strategy Director, James Towle.

Over the next four years, JLR will conduct real-world testing of Connected and autonomous technology using a fleet of 100 vehicles. Currently, it is running at least 10 main research projects in this area.

But that doesn’t mean the driver can take a nap while the vehicle claws its way through the jungle. There is a distinct difference between autonomous and driverless system capability, explained Towle. So R&D is concentrating on giving the driver focused technology support: “We aren’t looking at simply replacing the driver,” he said



Part of JLR’s autonomous all-terrain driving research is Terrain Based Speed Adaptation.

JLR is also determined to retain the established character of its products while imbuing a different type of emerging trust in the vehicle and its driver-support technologies.

Sensor building blocks

For its autonomous program, JLR is collaborating with **Bosch** in integrating next-generation sensor technology and processing power. “For example, we are adding more megapixels to stereo cameras,” said Bosch Customer Chief Engineer, Sven Lanwer. “This will increase in the future to provide more precise information; bandwidths are going up to give greater capabilities.”

Lanwer works closely with Chris Holmes, JLR’s Senior Manager Research, who said advances in sensor technology allied to software are providing significant new solutions. Ultrasonic sensors developed from those used as parking aids, are part of JLR’s predictive off-road autonomous R&D to anticipate surface changes.

While information quality needs to improve, increased quantity needs to be controlled. Is there a danger of giving the driver too much information by not filtering it sufficiently?

“It is a difficult question to answer,” stated Holmes. “What we are showing you [at JLR’s 300- acre Gaydon, U.K.,

proving ground] are some baseline building blocks that we are putting in place. It is the art of the possible. Technologies are evolving at a rapid rate based on sensor improvement and, coming together with software advances, are giving high level capabilities. So we are looking at many ways of how to advise the driver.”

This could include increased use of head-up displays and certainly of voice-command systems, the engineers told *Automotive Engineering*. It is no use in potentially dangerous or stressful situations putting up information on a screen while the driver’s eyes are focused where they should be—outside the cabin. Could tonal gradations of voice alert be considered to soothe and provide confidence without adding to tension? Possibly.

Certainly the driver must have confidence and belief in what the car is telling them, just as he or she has confidence today in brakes and steering operating safely.

Said Towle: “An intelligent car is never distracted because it is connected—it can even be aware of situations developing over the horizon. The aim of our autonomous all-terrain driving research is to make the self-driving car viable in the widest range of real life, on and off-road driving environments and weather conditions.”



All-terrain autonomous driving including vehicle convoying is a major part of JLR’s R&D program.

TECHNOLOGY Report



JLR Connect research into V2V data sharing could lead to a major safety advance for off-road driving in challenging conditions.

He added that over time the driver would indeed learn to “trust” the vehicle.

JLR is confident that this is going to happen. Peter Virk, JLR’s Director of Connected Technologies, added: “In less than three years I predict that every new car sold in the world will be ‘connected’.” But he also stressed that giving the right information at the right time to the driver was essential.

DSRC is key to conveying

While the company is making use of off-the-shelf and established technologies like ultrasonics, radar, stereo cameras, LiDAR and radio systems, these are being improved although it is more a matter of evolution than revolution.

Key autonomous or semi-autonomous programs demonstrated by JLR to the author included Terrain Based Speed Adaptation, which adapts speed automatically to changing surface conditions and also improves comfort via suspension settings. A stereo camera scans the route ahead with features mapped against different target speeds, making decisions about appropriate speeds for conditions.

Surface ID is a fundamental element of autonomous driving on any terrain. Artificial intelligence can assess surroundings and make what JLR describes as “appropriate decisions,” ultrasonic sensors scanning 5 m (15 ft) ahead of the vehicle. Surfaces including sand, gravel and snow are scanned-in to cre-

ate a database, which is cross-referenced with real time ultrasonic returns, allowing the vehicle to pre-emptively optimize relevant settings.

The Connected Convoy System using wireless Dedicated Short Range Communications (DSRC) uses information including vehicle location, wheel-slip, changes to suspension height and wheel articulation. The DSRC works with current production technologies such as All-Terrain Progress Control and Terrain Response settings.

Although seemingly useful for military applications (a **Land Rover** bailiwick), a JLR spokesperson said the R&D Connected Convoy system is focused only on civilian applications.

Overhead Clearance Assist, another new system, is aimed at both on- and off-road applications. It can cope with overhanging branches off road or warn the driver that roof-carried objects such as bicycles could cause a problem when entering a low-overhead parking structure. To operate the camera-based system, the driver simply adds the height of anything carried on the roof to the known height of the vehicle and would then be alerted by the system to any likelihood of entrance to a low height area.

On-road technologies under development include a “Safe Pullaway” system to prevent a vehicle colliding with one in front, typically at roundabouts or intersections when driver mental workload is high. A forward-facing stereo camera keeps watch on the area immediately

ahead of the vehicle. If the driver tries to accelerate from standstill and an object ahead is detected, the car will not move and a visual warning is shown.

Of particular interest in JLR’s on-road technology demonstrations was Co-operative Adaptive Cruise Control (C-ACC) using vehicle-to-infrastructure (V2I) and V2V communications to enhance existing radar ACC systems.

DSRC wireless is used to facilitate reaction within “a few milliseconds” to messages from the vehicle in front. The following vehicles would brake at precisely the same moment and rate as a lead car. This could facilitate autonomous platooning, with a gap time between vehicles of as little as 0.4 s. At present, depending on market, ISO standard for ACC is about 0.8 s.

Sampled by the author on a track, the effect was both worrying (initially) and reassuring (subsequently) as the system was activated. Following very close behind another vehicle improves radar ACC effectiveness but does concentrate the driver’s mind, with a need to overcome the reflex action of braking hard as the red lights of the vehicle ahead illuminate.

Quite what the law would make of this has not been defined. But like most aspects of autonomous driving, it will be legal and driver/vehicle occupant acceptance of such apparently esoteric systems that will determine their introduction—even though their efficacy may have been proven beyond reasonable doubt.

Stuart Birch

AUTOMOTIVE ELECTRONICS

In search of higher-energy-content batteries

As suppliers, automakers, and others join forces to develop high-performance battery components aimed at increasing the range of electric vehicles, current advanced batteries are edging closer to the end of their electrified vehicle lifespan.

"We've been very fortunate with almost 500,000 vehicles on the road that we haven't gotten a lot of those advanced batteries back yet. But there will be batteries coming out of service. And as technologists, as automakers, and as suppliers, we have an obligation to think through how we might use them, recognizing that the new ones cost half of what the old ones did," said Denise Gray, CEO of **LG Chem Power, Inc.**

Even with substantially decreased capacity these lifespan-limited power-train batteries still have energy, so a secondary life is possible. "You just can't put them in a landfill," Gray asserted, stressing industry collaboration is the best path to battery re-use.

Gray and other executives talked on assorted battery topics during a 'Leaders Debate' plenary session during the 2016 **Battery Show North America** in Novi, MI.

The experts forecast that in the next decade, electrified vehicle batteries could be using solid ion conductors that would enable the creation of batteries with more than 30% higher energy content than today's packs.

IONICS technology progress

Solid conductors with high ionic conductivity and other desired attributes would be a major innovation breakthrough, likely replacing today's conventional liquid electrolytes. The IONICS (Integration and Optimization of Novel Ion Conducting Solids) initiative aims to help bring solid-ion conductors and other innovations to commercialization.

Dr. Paul Albertus, Program Director for the **U.S. Department of Energy's** Advanced Research Projects Agency-Energy (ARPA-E), said the agency recently awarded \$37 million for 16 new IONICS projects, whose targeted goals also include a pathway to produce battery packs at less than \$125 per kW-h,

LG Chem Power Inc. CEO Denise Gray talks next-gen batteries during the 'Leaders Debate' session of the 2016 Battery Show. (Smarter Shows photo)



considerably less than current costs.

Focus areas for these academic, small business, and national lab IONICS projects include developing lithium conductors that can enable the cycling of lithium metal without short circuits or battery degradation; replacing today's graphite anode with a lithium metal anode and developing a solid separator not made from polycrystalline ceramics.

"We want to develop a solid separator with an amorphous glass structure that has a thickness of less than 20 microns," said Albertus, admitting that will be difficult to achieve for an inorganic material and at a targeted price of \$10 per square meter. "One vision of how this could work is to leverage some of the glass processing technologies that are used to make thin flexible displays," he said.

Li-S batteries by 2020?

Lithium sulfur and lithium metal have crucial roles in the IONICS initiative.

"In the lithium metal portion of the program, the goal is to develop higher-energy-density lithium batteries that would reduce mass, volume and cost, leading to longer-range electric vehicles. So we're working to get lithium metal out-of-the-lab and onto a clear commercialization pathway with a core

cell technology that would be relevant for automakers," Albertus told *Mobility Engineering*.

According to Dr. Ramesh Bhardwaj, Director of the X-Battery Group of **Google** parent **Alphabet**, today's battery materials are cost-heavy. "Li-S or lithium metal batteries with the potential of 350 to 400 W-h/kg are needed to reduce the cost of electric vehicles," said Bhardwaj. He noted that mass production of Li-S batteries is possible in the next three to five years.

"Sulfur is the cheapest material and it's also a raw material that comes from the oil industry. So if you can use sulfur to make batteries, then we can reduce the cost. However, the biggest challenge is it doesn't cycle very well," Bhardwaj said.

Gray of LG Chem pointed out that in recent years there has been a steady progression with battery systems overcoming assorted technical challenges.

"Take a look at where the technology has been and where it's going. It's not just because of the work that we're doing within our company," she said. "It really is working collectively with our OEM partners and with universities and governments in the U.S. and around the world to keep pushing the technology forward."

Kami Buchholz

TECHNOLOGY Report

AUTOMOTIVE ELECTRONICS

SAE Battery Standards committees prepare for next-gen chemistries

"We're just at the beginning of a steep growth curve for both electric vehicles and energy storage, and **SAE International** is going to play a huge role in that by setting the standards that are necessary to move it all forward," said Robert Galyen, chairman of SAE's Battery Standards Steering Committee.

Galyen oversees 22 ground vehicle SAE battery committees. He spoke with *Automotive Engineering* about battery trends, technology, grid storage and standards, on the opening day of the 2016 Battery Show in Novi, MI.

As lithium batteries become commonplace in electrified vehicles, battery standards are evolving. SAE's J1797 standard for electric vehicle battery packaging set the stage 20 years ago for vehicle electrification.

"We put J1797 in 'stabilized mode' within the last two months because it's antiquated for what's happening today," said Galyen, noting J1797 was written in 1996 and became an industry standard in 1998. "That was at a time when nickel metal-hydride and lead-acid batteries were being used," he explained.

Specific Li-ion battery standards address a variety of aspects, including materials, labeling, and safety.

"We have a cadre of engineers working on all the standards specific to today's Li-ion batteries, and we have a committee specific to next-generation batteries as we want standards to be ahead of when next-generation battery technology reaches the market," Galyen said.

Packaging system needed

SAE's Advanced Battery Concepts Committee will release their first technical information report this year.

"We typically write recommended practices, which are put in place to drive the industry to a common footprint or a common methodology of application," Galyen explained. "But this committee's core role is to inform the general public about what's going on."

SAE's Ground Vehicle and Aerospace groups share information related to the safe shipping and transport of Li-ion batteries.

"Because we have such a large group



Robert Galyen, SAE's ground vehicle group battery chair, is the CTO of Contemporary Amperex Technology Co., Ltd. Based in Ningde, China, CATL specializes in advanced battery R&D and manufacturing. Galyen is shown at CATL's booth at The Battery Show 2016.

of people working on Li-ion batteries for products that go on vehicle applications and bus applications, it only makes sense to have these experts involved," said Galyen, noting the aerospace group's G27 is responsible for writing this battery packaging shipment safety standard.

The U.S. and many other countries have outlawed the shipping and transport of Li-ion batteries in the cargo bay of passenger aircraft, an area that's unattended and inaccessible during flight.

"We need to create a packaging system that will contain these Li-ion batteries in such a way that fire cannot propagate," he asserted. "We don't want the fire extinguishing system to be needed in the first place."

Autonomous EVs

Galyen expects all SAE Battery Standards committees will stay busy for some time, given the brisk growth rate of electrified vehicles in various global markets, particularly China. He believes the automotive sector is on the cusp of an "energy revolution."

An additional boon for electrified powertrains will come from the advent of SAE Level 4 and 5 autonomous vehicles. According to Denise Gray, CEO/President of **LG Chem Power Inc.**, who spoke at the conference, autonomous vehicles and electrified powertrains go hand in hand. She noted that key support technologies include advanced batteries.

Kami Buchholz

AUTOMOTIVE SOFTWARE | SIMULATION

Making Multiphysics fast and convenient

Mimicking real life interactions in complex products like automobiles or aircraft often requires a Multiphysics approach. It requires combining, for example, simulations of combustion, heat transfer, fluid flow and stress analysis to truly understand whether an engine is going to perform reliably in real-world conditions.

As computer memory grows and software developers learn how to create efficient codes, practical Multiphysics is expanding. However, challenges remain beyond the technical—the sheer intellectual complexity in creating simulations and scenarios that span such a range of knowledge. Increasing technical capabilities now highlight some human limitations: creating a valid Multiphysics model often is confined to a small group of highly specialized, highly educated 'power' users.

Sweden-based CAE simulation tools specialist **COMSOL** is tackling this human complexity problem in two ways: with specialized modules and dedicated "apps" deployed in Windows or even on a smartphone. Both approaches are aimed at making software easier to use for a broader group of engineers. This is especially important for mobility-industry engineers and managers, explained Dr. Valerio Marra, COMSOL's Marketing Director.

"Putting together an R&D team is quite an endeavor—to find them, to train them in your industry and for them to find the right tools," Dr. Marra told *Automotive Engineering*. "If you want to keep up with progress in innovation in the industry, you have to free up their time." He emphasized that the answer is not always to hire more engineers. These additional engineers would need training on the core COMSOL Multiphysics product as well as deep understanding of the underlying physics.

"What managers should know is there is a technology now that engineers can use to package the complexity of their knowledge into an 'app,' so that other engineers can go on with their design work," he said.

Building apps and interfaces

COMSOL is not the only CAE company offering such tools for packaging and hiding complexity. Offering it as a specialty in Multiphysics should come as a welcome addition for those attempting to solve higher-fidelity problems where multidisciplinary interactions are key.

A COMSOL app is a multiphysics model wrapped in a custom user interface. The user interface is built through a graphical, interactive tool called the Application Builder. Apps can be deployed as a client in Windows, or even through a web browser, by connecting to a local installation of COMSOL Server software. They can also appear on a smartphone.

“Building an app is especially useful

when there are repetitive operations that need to be done, perhaps even on a routine basis. When accessing complex software becomes a problem, accessing the app that hides much of that complexity becomes a valuable asset,” explained Marra.

The company claims that custom applications can be created for anyone from technicians, support staff, designers, to customer service representatives, “empowering them to make on-the-fly design iterations and report generation,” he said.

Specialty modules

In a variation on packaging complexity, the latest update of the COMSOL suite includes the new Rotordynamics Module. It helps engineers in analyzing

vibrations due to gyroscopic effects in rotating machinery, evaluating critical speed, whirl, and bearings. It is targeted for users who design or evaluate turbochargers, turbines, pumps and electrical machinery in the automotive, aerospace, energy and marine sectors among others.

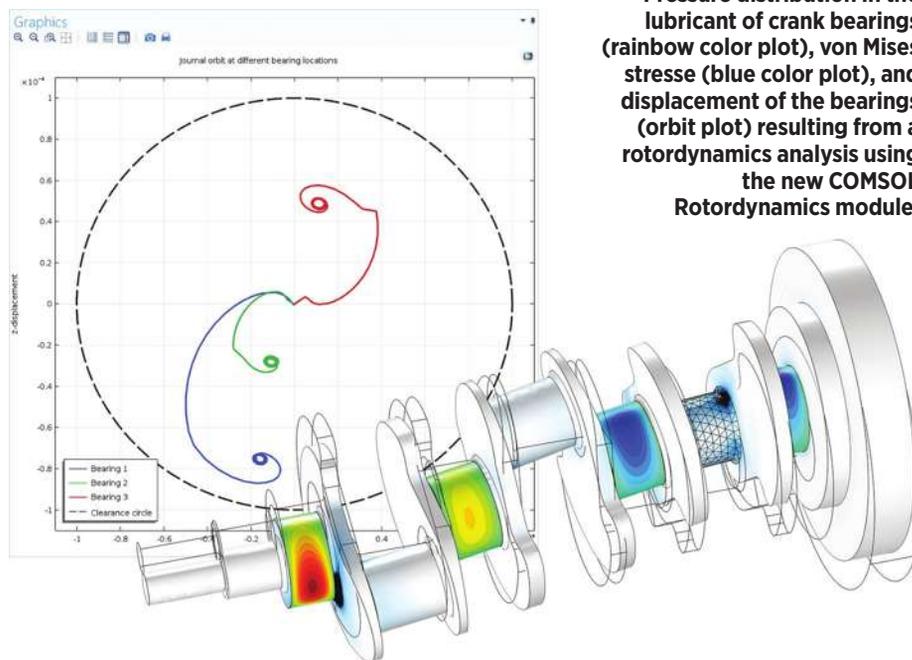
The company notes that additional tools for modeling geared rotors are available when the Rotordynamics Module is combined with the Multibody Dynamics Module. Postprocessing capabilities include creating Campbell diagrams, modal orbits, harmonic orbits, waterfall plots and whirl plots. The new module is in addition to 28 other modules for specialty applications, including electrical, structural & acoustics, fluid & heat, and chemical applications. The core COMSOL Multiphysics software is required to run any of these add-on products.

A related improvement to the latest release of COMSOL is speedier processing of larger models and meshes. The company emphasizes models with several thousand domains and boundaries, with functionality speedups including a 10-times speed improvement in selections of domains and boundaries, virtual operations for mesh preparation, swept meshing and OpenGL rendering and a 5-times improvement in CAD imports.

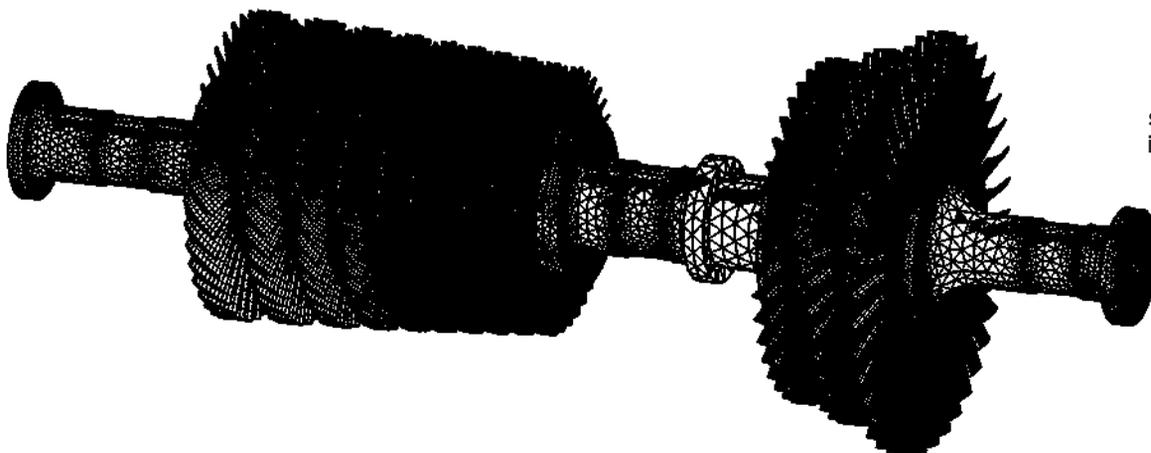
One of the past issues with simulating Multiphysics has been the size of the resulting numerical model, but increasingly fast and inexpensive computing is giving numerical specialists the opportunity to fine-tune codes to ingest and compute ever larger models.

For related information, see “Simulation apps for virtual prototyping” (<http://articles.sae.org/14960/>).

Bruce Morey



Pressure distribution in the lubricant of crank bearings (rainbow color plot), von Mises stress (blue color plot), and displacement of the bearings (orbit plot) resulting from a rotordynamics analysis using the new COMSOL Rotordynamics module.



A combination of a tetrahedral and swept mesh of a gas turbine is shown. Increasing speed in handling large models will make it easier for Multiphysics simulation, according to the company.

AUTOMOTIVE ELECTRONICS | SOFTWARE

OTA updating brings benefits, challenges

The race to build up an infrastructure for over-the-air (OTA) updating is heating up as suppliers go all-out to gain a spot in a field that's expected to see momentous growth. Warranty costs, cybersecurity and the expectations of smartphone users are among the factors driving developments throughout the supply chain.

OTA is quickly moving beyond the luxury vehicles typified by **Tesla's** highly-publicized usage. **Cummins** added OTA capabilities on its X12 and X15 heavy-duty engine lines, which will ship in 2017. Cummins Connected Calibrations permits wireless engine tuning and calibration in the field.

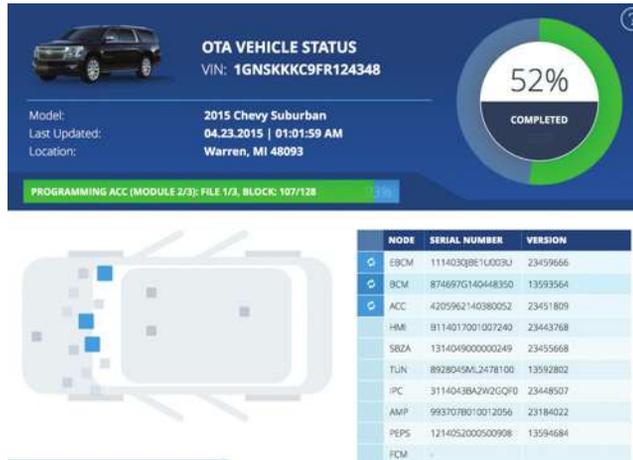
To date, most efforts in OTA updating has focused on infotainment and telematic systems. Cummins' move highlights the broad applications that are expected to show up in the next few years. Some analysts feel that controlling warranty costs will be a key driving force for the field.

"In the past two years, software has accounted for a significant portion of recalls, and I daresay 2016 will show a higher percentage of recalls for software issues," Roger Lanctot of **Strategy Analytics** said in a recent webinar. "A key factor for OEMs is warranty cost avoidance."

As connectivity expands, hacking and other threats will also fuel demand for OTA. Security programs will have to evolve to meet new threats over the vehicle's lifetime. The expectations of consumers used to adding functionality to smartphones is another factor fueling growth projections. That's forcing engineering teams to address a number of different needs.

"OEMs need people who look at adding capabilities two or three years after the design is completed," said Yoram Berholtz, Director of Business Development at **Argus Cyber Security**. "This will be a new paradigm for design teams. Telematic and infotainment hardware will also need to change, more memory and more computing power will be needed."

The huge volume of software and the number of controllers on vehicles make updating a far more complex task than revising handheld computing platforms.



Over-the-air updating technologies are being developed by a range of suppliers such as **Movimento**.

Hardware and software from many different suppliers will have to work together in an environment with extremely high quality and reliability levels.

"Automakers never get all their components from a single Tier 1," said Scott Frank, **Airbiquity's** Vice President of Marketing. "They have multiple software tools and multiple software installers, so they need a central management function to pull all that together."

Building a complete OTA system requires plenty of work inside and outside the vehicle. On-board systems will have to have extra storage space to hold both updates and older software that can be used as a fallback if problems arise. Architectures will have to support communications from the cloud down to individual ECUs.

"Flattening the architecture makes sure that each particular endpoint in the car can authenticate to the cloud individually," said Mahbulul Alam, CTO at **Movimento**. "What has been done between the cloud is we are getting more CPUs connecting to the cloud and more CPUs into the vehicle and deeper into the vehicle."

This is not only for infotainment but goes deeper to enable encryption. "They can put the crypto-algorithms directly where the source is and protect the data as it is delivered to end points in the car," Alam explained.

Communications channels are another important aspect for developers. Cellular links can cost consumers money, so many strategists say that Wi-Fi might be a good option. That's partially because the network's short

distances mean that cars will be parked at home or offices.

However, the costs of cellular aren't expected to be large enough to impact owners who don't utilize Wi-Fi.

"Most people plan to do a lot of updating via Wi-Fi, though there will be instances where software is updated over the cellular link," Lanctot of Strategy Analytics said. "In most cases, the payloads will be small enough that there won't be concern for the cost of a cellular connection."

Concerns about payment will probably be dwarfed by privacy issues. Once buyers own the vehicle, they can have a say in what happens to it. Issues like recalls and notifications will be closely examined in public forums.

"Will consumers have to pay for updates? Will consumers have to be notified before updates are downloaded?" Lanctot asserted. "For recalls, there may be further notification involved. Privacy will be an important factor."

Though updates sent to vehicles are widely discussed, observers note that pulling information from vehicles is important for OEMs. In addition to maintenance information that can be sent to dealers, automakers will collect data on consumer preferences and components. This input will help them see how new products are being used and how components perform.

"With a new car, you may want to run checks every day to see how new parts are working," Frank said. "You may only check every month for an older vehicle."

Terry Costlow

OFF-HIGHWAY ELECTRIFICATION

Full-electric drivetrain for HD vehicles the result of supplier alliance

Engineers at Colorado-based **UQM Technologies** have collaborated the past several months with their counterparts at **Eaton's Vehicle Group** and **Pi Innovo**, both located in Michigan, to develop a full electric drivetrain system for the medium- and heavy-duty EV markets.

Eaton experts are developing and supplying to UQM a 2-speed transmission for an EV (electric vehicle) application, and Pi Innovo engineers are responsible for the transmission control unit. The components are integrated with UQM's current PowerPhase HD220/HD250 motor and inverter system to create a full electric drivetrain system called the UQM PowerPhaseDT.

Benefits of the new drivetrain, according to Josh Ley, vice president of technology for UQM, include better packaging, efficiency, greater payload capacity and lower cost when compared with direct drive or single speed drivetrain strategies.

"Perhaps the biggest benefit is the fact that the 2-speed transmission keeps the electric motor operating in the highest efficiency region for a greater portion of the drive cycle," said Ley. The Eaton 2-speed transmission provides a greater speed and torque

range from what would normally be possible in a direct drive system, he noted, allowing a smaller electric motor to drive large vehicles.

First gear ratio is 3.53:1, and second gear is 1:1. Peak torque is rated at 3050 N-m (2250 lb-ft), with a continuous torque range of 1200-1420 N-m (885-1047 lb-ft). Rated power ranges from 150-180 kW, with peak at 250 kW.

"Even with the transmission, the total size and weight [of the system] is smaller than the motor that [typically] would be employed without a transmission," Ley explained to *Mobility Engineering*. "Our motor is 250 kW, but it is very small for that power level. Motor's size basically [depends] on torque required; therefore, the transmission allows massive downsizing."

Efficiency benefits also lead to cost reduction. "The high efficiency band is large so you only need 2 speeds as opposed to 4 or 5 to match the power band of an engine," he said. "Higher powertrain efficiency translates directly to increased range or reduced battery costs—or both."

The drivetrain is targeted to electric and range-extended commercial vehicles up to 18,000 kg (39,700 lb). Ley

believes the system would be an "excellent" fit for off-highway applications.

"The low-range first gear can help off-road vehicle makers to provide a very low overall drive for low-end torque," he said. "Similar designs for both the UQM motor and Eaton transmission have been used in off-road applications [previously]."

UQM is ready to deliver prototypes to customers this fall as part of the initial pilot program. The company already has secured **Hybrid Kinetic Group**, **Wuzhoulong Motors** and **ITL** for a **Yangtse** full-size bus in China, and California-based **Adomani** in the U.S. Applications for early PowerPhaseDT adoption include transit buses and school buses.

Start-of-production units are on target for early 2017 delivery.

"It is a short development cycle, but most of the major components had been validated and proven in applications previously. The focus of the development is system-level powertrain controls," Ley said. "We are designing the system such that system controls integration with vehicles is very convenient, while still supporting expanded functionality. The Pi Innovo and UQM teams have extensive experience with vehicle systems integration."

Beyond satisfying customer drive cycle needs, the full electric drivetrain system will be a contributor in helping vehicles meet more stringent environmental regulations, Ley believes.

"Phase 2 regs are aggressive. I would anticipate many of the OEMs going full electric, series hybrid or plug-in range-extended electric vehicles (REEV)," he told *ME*, referring to the recently finalized U.S. **EPA** and **National Highway Traffic Safety Administration** greenhouse gas (GHG) rules for medium- and heavy-duty vehicles from model year 2021-2027.

"This drivetrain system applies to all three types of vehicles. The higher efficiency of the system will decrease carbon emissions for the hybrids. Essentially the pure electrics are no emissions inherently, but it certainly improves the business case of the fleet having lower kW-h consumption from the utility," he said.

Ryan Gehm



The new UQM PowerPhaseDT full-electric drivetrain is targeted to electric and range-extended commercial vehicles up to 18,000 kg (39,700 lb). The system also is an "excellent" fit for off-highway applications.



Most of the major components have been validated and proven in previous applications. The real focus of the development program: system-level powertrain controls.

TECHNOLOGY Report

OFF-HIGHWAY INTERIORS

Automotive influence on off-highway cabs



Thirteen partners jointly developed the Genius CAB concept envisioned for construction, agricultural and industrial forklift application. The cab consists of near-series components and systems.

Describing new features and technologies for off-highway vehicles as “automotive-style” sometimes comes off as marketing hype—words meant to tap into views that passenger vehicles are more progressive and closer to the cutting-edge. But often the link is more substantive—engineering know-how actually migrated from pavement-bound machines to those that call dirt home.

The latter scenario holds true for a recent concept cab envisioned for construction, agricultural and industrial forklift application that consists of near-series (capable of employment in off-highway within the next two or three years) components and systems. Many among the 13 partners that jointly developed the Genius CAB are firmly established in the automotive industry, and quite a few of these suppliers note the influence their automotive arms played in their contributions to the project.

Robert **Bosch** is one such company. The Tier 1 contributes the body computer, which enables centralized control of the sensors and actuators via CAN (SAE J1939), LIN or directly, as well as the ultrasound sensors integrated into the exterior of the Genius CAB to detect dangerous situations by displaying relative positions and nearby obstacles. The

information is communicated to the operator via the display terminal and a **Hella ScenarioLight** installed in the roof.

“We have a lot of experience [with systems integration] coming from the automotive industry, so using that on a construction machine really gives us a big advantage,” said Kai Bohne, Senior Manager of Sales and System Engineering, Commercial Vehicle and

Off-road Business. “Our main business in off-highway currently is hydraulics, fuel systems and aftertreatment systems; HMI [human-machine interface] and electronics is the next step on top of that.”

The ultrasonic sensors are “similar technology from pass car,” he said, which would be mounted in the bumper for advanced warning systems.

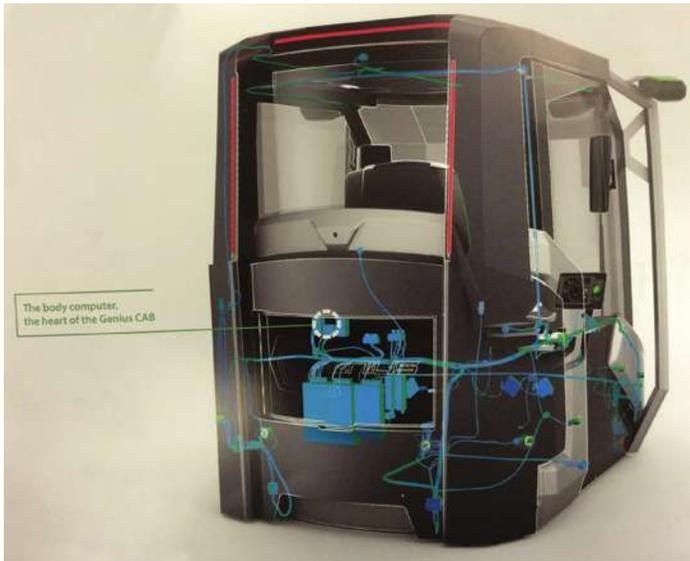
Hella, another major automotive supplier, notes that development of the cab’s LED worklights was based on its previously-deployed-in-automotive matrix beam technology. Subdivided into multiple units that can be dimmed up or down according to the situation, matrix beam LEDs avoid “dazzling” operators. For example, while the bucket of a wheel loader is raised, it is not illuminated and the light is routed past it.

During the 18-month development process for the Genius CAB, systems integration was a key focus for the partners. One example is the aluminum front beam structure, manufactured by **Fritzmeier Systems**, doubling as a heat sink for the integrated matrix beam worklights.

The Genius CAB also taps into a trend that is huge in automotive now: lightweighting. The cab features a newly developed modular structure that results in a 30% reduction in weight. A “soft cab” is made from welded aluminum special profiles, and a steel EXO-ROPS/FOPS (rollover protection



Grammer supplied a complete user-interface system consisting of a suspended driver seat, electronic multifunctional armrest and a 12-inch multi-touch display. (Photo by Ryan Gehm)



Bosch contributes the body computer, which enables centralized control of the Genius CAB's sensors and actuators via CAN (SAE J1939), LIN or directly.

system/falling object protection system) is attached over the cab as an add-on. This exo-structure can be variably adapted to suit the weight of the machine, according to Fritzmeier, ranging from 10 to 50 t (11 to 55 ton).

Instead of mirrors, a camera system combined with a variable view reversing camera from **MEKRA Lang**—used for the first time in a cab for an off-highway vehicle—provides enhanced surround visibility, especially in the dark. The system, which has been demonstrated in future-looking on-highway trucks, displays hard-to-see areas at the rear of the vehicle on screens inside the cab, while compensating for the vehicle's vibrations.

Automotive cable supplier **S.M.A. Metaltechnik** also contributed to the



A peek inside the Genius CAB, and view of the cab structure including external A-pillar that doubles as handrail with integrated signature lighting from Hella. (Photo by Ryan Gehm)

project, supplying an internal heat exchanger that the company claims is the first “efficiency boosting component of this nature” to be used in a construction machine. Involved in the cab's air-conditioning system since the concept phase, S.M.A. decided up front to use components that had undergone successful testing and deployment in the automotive sector, including high-density connection technologies and refrigerant hoses featuring low loss and high flexibility.

The inspiration behind the HMI setup developed by **Grammer** in collaboration with **Dresden University of Technology** was the car interior—having multifunctional controls at the operator's fingertips, according to Marko Boving, Product Manager, Grammer EiA Electronics. “Why can't you do that in an excavator? This is what we focused on,” he said.

As with drivers on the road, operator distraction is a major consideration in HMI design. “Although we can show a lot of information, you can disengage [certain functionalities] or not show them. For OEMs, it's easy for vehicle platforms; it's just software, so the modification factor is high.”

Boving used a term common in automotive, of course, to describe the discipline: cognitive systems engineering. “We engineer what you can perceive, and that's what we did here.”

If the Genius CAB concept is an accurate indicator, it's easy to perceive automotive technologies and sensibilities having an even greater influence on off-highway cabs in the near future.

Ryan Gehm

AUTOMOTIVE MATERIALS

Self-piercing rivets shoot for vehicle-lightweighting applications beyond aluminum

Growth of lightweight vehicle body and closure panel applications in the coming years, and particularly greater use of aluminum, is driving increased use of self-piercing rivets as a high-volume structural joining solution. **Ford's** aluminum-intensive F-Series program brought rivet-bonding into the mainstream, following lower-volume applications by **Audi, BMW, GM** (Corvette), **JaguarLandRover** and **Tesla**.

The combination of self-piercing rivets (SPR) and robotically-applied structural adhesives creates a robust joint with other benefits. The rivets clamp the adjacent metal panels together to allow the adhesive-bonding agents sufficient time to cure while the assembly goes through the body and paint shops. Without the rivets, a bonded-only assembly could not be produced at a line rate competitive with spot welding, according to experts.

“Because self-pierce riveting is a solution that can join aluminum and other multi-material designs, we see a significant increase in SPR usage worldwide over the next few years,” said Dr. Matthias Wissling, Manager of Fastener Engineering for **Stanley Engineered Fastening** (SEF), formerly **Emhart Teknologies**.

Wissling and other SEF officials recently sat down with *Automotive Engineering* at the company's North America automotive headquarters in Troy, MI, to talk about SPRs and structural-joining innovation.

SPRs are well-entrenched on European vehicle applications after their 1990s debut on the aluminum-bodied Audi A8. As automakers in North America turn to aluminum sheet and other lightweight materials that can't be joined by traditional welding techniques, SPRs are gaining momentum.

Use of aluminum sheet for vehicle body and closure parts is forecast to climb from less than 200 million pounds in 2012 to approximately 4 billion pounds by 2025, according to

TECHNOLOGY Report



“We design, engineer and manufacture the fasteners and fastener assembly systems that attach the fasteners to the body-in-white,” said Stanley Engineered Fastening’s Dr. Sivakumar Ramasamy, standing near the robot cell in the company’s Troy, MI innovation center. (Kami Buchholz)



Stanley Engineered Fastening self pierce rivets were used to join the sections of the Range Rover Sport’s B-pillar.

Ducker Worldwide’s 2015 North American Light Vehicle Aluminum Content Study. Of the total, 85% of the material will be used for hoods, 46% for doors, and 18% for complete bodies. By comparison less than 1% of bodies were aluminum-intensive in 2015,

the study noted.

While spot welding remains the most common method for joining steel body-in-white (BIW) panels, advanced mechanical fastening is an increasingly popular option. The SPR process can join aluminum, steel, plastics, carbon-fi-

ber-reinforced composites, and combinations of materials without the need for a pre-drilled hole.

SPRs don’t require heat to complete the assembly process, the experts noted, and the technique can be used to join all joints, such as aluminum-to-steel and steel-to-steel, on the same BIW. “This is important because each additional joining technology used for a BIW adds additional complexity and cost,” said Dr. Wissling.

SEF offers several different joining technologies, ranging from metal clips and inserts to studs and SPRs, as well as various fastening assembly systems, according to Dr. Sivakumar Ramasamy, SEF’s Vice President of Breakthrough Innovation.

“The 2025 CAFE [Corporate Average Fuel Economy] requirements are dictating a greater use of lightweight BIW materials, so that’s driven more types of fastening methodologies for the BIW and for attaching parts to the BIW,” said Dr. Ramasamy.

“My directive is to come up with innovative solutions—which could be products, processes, the way we do business—for whatever is coming next in the industry,” Ramasamy said. His newly-formed team of engineers and marketing specialists will begin their duties from a location near Giessen, Germany prior to 2017. The team’s sole focus is innovation.

“Could the autonomous vehicle be plastic-bodied? If so, what would be the fastening method for that vehicle with all of its body- and closure-attached sensors? It might be a plastic rivet or gluing that meets the requirements,” Dr. Ramasamy opined. “The innovations team needs to understand all of the emerging trends and come up with solutions.”

For more than 30 years, the company’s core product line was spot welding. As BIW materials have shifted, the fastening options have evolved.

The SEF innovation team’s double-digit percentage budget allocation is no accident. “We want to grow this business through innovation. Being able to fasten lightweight materials is one thing,” said Dr. Ramasamy, “But there are other things we can do. Because beyond 2025, something else is coming.”

Kami Buchholz

Focus on advanced safety systems and human-factor interventions

Abstract

The automotive industry is moving toward a stage that anticipates the probability of accidents and instructs a safety system to take immediate action. Safety systems in the automotive domain protect vehicle occupants—and even pedestrians—from accidents. With the help of advanced technologies, accidents can be avoided and many can be saved from major injuries.

This paper provides an overview on the operations of various advanced safety systems such as pre-crash, electronic brake assist, lane-keeping support and others. It also examines the driver's requirement to respond actively according to system expectation and to use these systems effectively. This paper provides a brief on feasibility studies for the India market.

Introduction

Initially, passive systems such as airbags, seatbelts, etc. were developed to minimize injuries during a crash. Then, preventive measures such as improving visibility, tire traction, headlights, etc. were developed to reduce the probability of getting into an accident. Now with the advent of advanced technology, systems are being developed to actively avoid accidents and provide maximum protection to vehicle occupants and even pedestrians.

More than 70% of accidents and injuries are caused by a delay in driver recognition of the situation. A delay in driver recognition leads to a delay in action, which often leads to an accident. Advanced safety systems emerged to provide a warning and at certain times control the vehicle if the system anticipates collision is unavoidable.

Precrash systems

Precrash systems identify forward objects and first notify the driver. The system waits for the driver to apply brakes, but if the driver has not braked appropriately, the system will automatically apply the brakes. The seatbelts also are tightened more during this situation to most-effectively restrain occupant movement.

Millimeter-wave radar and stereo camera vision is used to identify the potential forward collision (see Figure 1). Radar can detect vehicles, obstacles and pedestrians to supplement camera

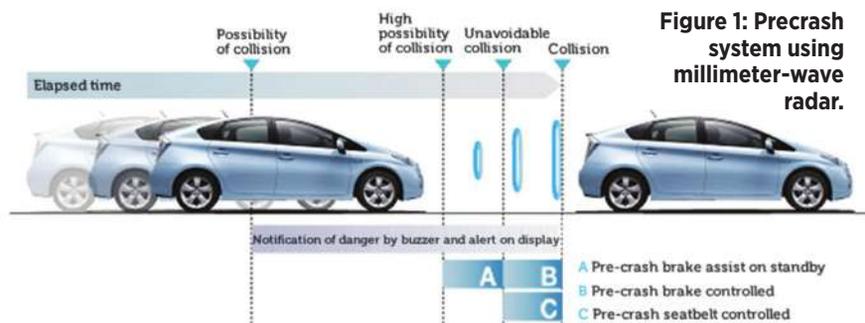


Figure 1: Precrash system using millimeter-wave radar.

information. These sensor inputs are processed and sent to brake unit and restraint control module to activate the brakes and restraint control system.

A camera installed in the cabin also can be used to sense driver eye movement. With the help of image processing, the system can determine whether the driver is alert. This information, along with object detection by radar, is processed and sent to the instrument cluster to provide an audiovisual warning.

Early-warning vehicle-to-vehicle communication

This system employs a wireless communication network to advise vehicles of their relationship to one another.

Some OEMs use Vehicle-to-Vehicle (V2V or C2C) communication technology for sharing data; V2V technology enables the car to share its location and certain operating parameters with surrounding vehicles. Using this information, surrounding vehicles would warn the driver. This technology can use dedicated short range communication (DSRC), a type of wireless signal in the same range as Wi-Fi. Unlike radar, it can be transmitted through solid objects like buildings.

Human-factor intervention: The driver need to enable this feature by a pushbutton or through HMI. Instead of scanning the road ahead, drivers are alerted by their own vehicle if vehicle in front is applying its brakes. The warning is given to the driver, who is required to brake to slow the vehicle.

Cooperative intersection collision-avoidance systems (CICAS):

Intersection collision avoidance systems can be classified as either infrastructure-only or as infrastructure-vehicle cooperative. Infrastructure-only systems rely solely on roadside warning devices to communicate with drivers. Cooperative systems communicate information directly to vehicles and drivers. Major advantages of cooperative systems lie in their capabilities to improve the interface to the driver and hence to virtually ensure that a warning is received.

There are several variants of CICAS:

Stop Sign Assist System is an infrastructure-based system designed to help drivers on low-volume roads who, after stopping at a stop sign, wish to cross or turn into traffic on higher-volume, higher-speed roads. The system will synthesize data from roadside sensors, processors, messaging signs and communications technologies to provide information to drivers on the gaps in traffic that allow for safe passage.

Signalized Left-Turn Assist is an infrastructure-based system that will provide information to drivers performing unprotected left turns to judge the gaps in oncoming traffic as well as inform them when other users, such as pedestrians or bicyclists, pose hazards to completing a safe left turn (see figure 2).

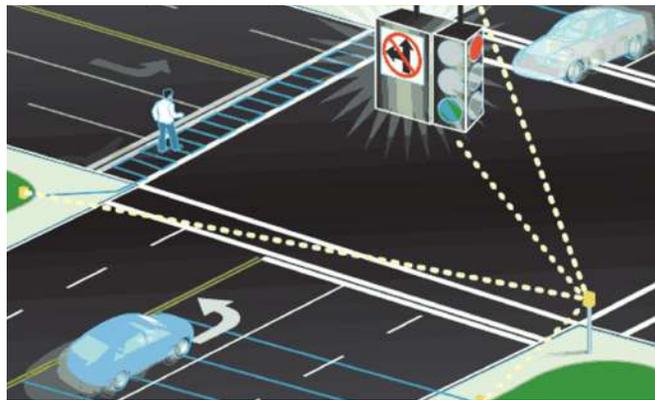


Figure 2: Left Turn Assist System – Blue car waiting for dynamic infrastructure traffic sign.

Traffic-Signal Adaptation informs the driver through wireless medium to stop the vehicle when the system anticipates a red light. This application combines infrastructure sensors and wireless communication to detect a dangerous situation when a vehicle violates a red light and can potentially collide with other vehicles. In this case, CICAS-TSA triggers a red light in all directions to protect drivers from an imminent danger.

Technology involved: the CICAS-TSA system relies on DSRC to exchange safety messages in real time between a RSU installed at an intersection and an OBU installed on the vehicle. The OBU monitors vehicle dynamics, position, lane of travel, and distance to the stop line. It assesses the risk of violating intersection signals, and warns the driver of imminent danger if a violation is predicted.

The information included in these messages comprises current Signal Phase and Timing (SPAT) for the local traffic signal controller and digital map of the local intersection called Geometric Intersection Description (GID). The OBU determines the probability of a violation by continuously assessing the vehicle speed, SPAT, and the vehicle's distance from the stop bar in the lane of travel. The OBU issues a warning to the driver if it predicts that, given the current operating conditions, the vehicle is going to violate the signal to enter the intersection.

Human-factor intervention: CICAS systems provide only a warning to the driver, who should make cautious decisions based on the input.

Feasibility study: In India, using the Xbee radio module, low-cost networks can be established between vehicles and the infrastructure, with power tapped from street lights and traffic-sign posts to operate Xbee modules.

Safety systems for teenagers

Parents program the parameters such as available speed, audio volume, etc. to a limited value for a key used by young drivers. Parents use a web-based app to see the vehicle's location and also can define the area of vehicle operation.

Technology involved: Ford has developed My key™ technology that uses a special transponder-chip key to activate this safety system. Similarly, Hyundai has developed Blue Link technology and GM has Family Link technology.

Human-factor intervention: Vehicle operating parameters are programmable using the administrator key; drivers should be aware that overtaking and other actions will be governed by the programmed limits.

Feasibility study: In India, this can be implemented with the existing technologies like PATS and keyless vehicle. Having different identifiers for different keys, it is possible to associate different personality settings for different keys.



Figure 3: Camera monitoring the lane.

Lane-keeping support

Lane-keeping support is one of the first steps toward the automated highway populated with vehicles able to navigate without input from the driver. This system monitors whether vehicle is running within the road lane. If it determines the vehicle is drifting from the lane, the driver can be alerted to take corrective action or the system can automatically apply corrective force to the steering to return the vehicle to the lane.

Technology involved: A forward-looking camera monitors the lane (see Figure 3). With the help of image processing, the camera sensing deviation and informs driver interface to issue the respective warning or signals the steering to take corrective action.

Human-factor intervention: The driver takes control once the warning is issued to correctively steer. Sensitivity regarding lane deviation and intensity of driver alert methods can be adjusted.

Feasibility study: In India, lane-keeping functionality will require a huge infrastructure upgrade to create clear lane divisions everywhere.

Conclusions

The future of automotive safety systems certainly is an integrated, vehicle system-level approach. Change in infrastructure development is required to derive the benefits of next-generation safety systems; considering the growth in population and economy it is essential to improve the infrastructure to align with the developments in automotive safety systems.

Though there is a wide variety in safety-system development, human-factor involvement typically is required to most-effectively use these systems—and to use these features to the fullest extend, awareness on how they interact with the vehicle is essential. Human factors are not necessarily limited to unsafe driving behaviors like excessive speeding and tailgating; age, driving experience, attention level and vehicle maintenance all can have a downstream effect on the performance of safety features. ■

This article was adapted from an SAE technical paper, "Focus on Advanced Safety Systems and human factor interventions," by Kannan Elumalai, Visteon Technical and Services Centre.

THE IMPACT OF REACH ON THE AVIATION SECTOR



Considered the most comprehensive chemical-regulation legislation to date, REACH presents serious ramifications for the aviation industry.

REACH (Registration, Evaluation, Authorization and Restriction of Chemicals) is a European Union regulation which came into force on June 1, 2007. Its aim is “to protect human health and environment through sound management of chemicals while enhancing competitiveness and innovation of the European chemical industry.”

The regulation is set for a three-phase adoption period that began in 2010 and is slated to finish on June 1, 2018.

REACH applies to “substances” (the term used in the legislation for chemicals) manufactured or imported into the European Union in quantities of 1 tonne or more annually. It is applicable, with some exceptions, to all substances on their own, in a mixture or in an “article” (the term used in legislation for components/products).

The REACH regulations set guidelines regarding phasing out of certain substances and to inform end consumers about hazardous substance(s) present in the product. In some cases, the substances are banned in entirety or for use subject to certain conditions. Also, the threshold of 1 tonne doesn’t apply to substances that are banned or restricted. In other words, even if a substance is manufactured or

imported in European Union in quantity of less than 1 tonne, it still can be restricted if that substance is deemed to pose unacceptable risk to human health or the environment.

In case of non-compliance, companies can face hefty penalties decided by individual member states of the European Union. Belgium has set maximum fine of €55 million, whereas the UK has not fixed any maximum limit on the fine that can be imposed. Apart from fines, non-compliance also can result in criminal proceedings and executive imprisonment.

Initially perceived as regulation for the chemical industry, REACH has jolted the aviation sector, which uses hazardous chemicals in minimal quantities. The effect of the regulation can be felt throughout the industry’s supply chain and lifecycle of the aircraft.

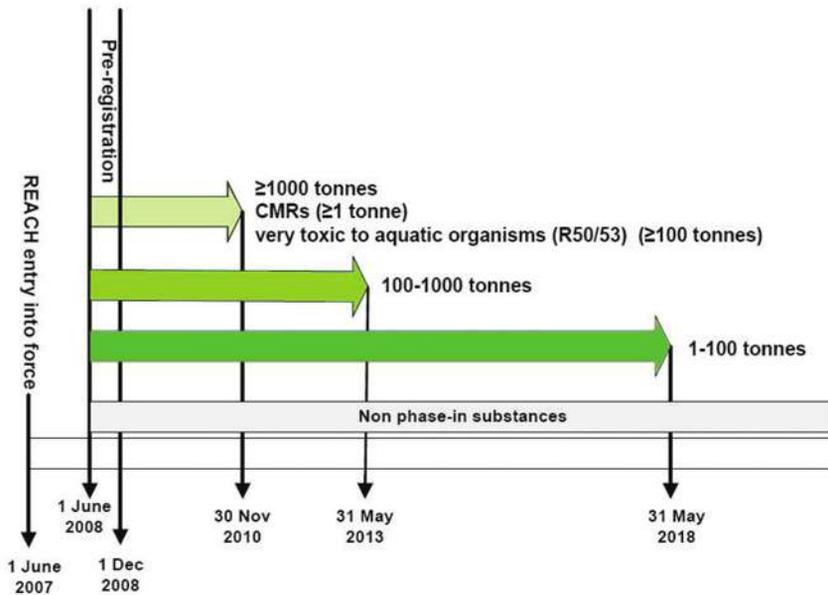
Challenges faced by the aviation industry in complying with REACH

- **Time and cost for certifying a product:** any component in an aircraft must pass stringent material-qualification and product-certification requirements, both at the component level and at the system level. This process intrinsically involves considerable time and cost—any changes made to the component because of REACH regulations will increase the financial burden on OEMs.
- **Finding alternatives:** The materials used in aircraft must perform in severe environmental conditions and these materials have matured after many tests and iterations. Any new restriction on these substances can unsettle the entire industry. The most suitable example may be hexavalent chromium compounds. Chromium (VI) compounds are on the REACH authorization list; substances on the list cannot be used after a set date (called sunset date) if prior authorization is not

THE IMPACT OF REACH ON THE AVIATION SECTOR



Typical compliance-assessment process.



The REACH regulations are scheduled for adoption in three phrases from 2010 to 2018 (source: Chemical Inspection & Regulation Service).

received from the European Chemicals Agency (ECHA), the REACH regulating authority. Chromium (VI) is used for hard-chrome plating in landing gear and other components and there is no comprehensive substitute for it. Multiple stakeholders are involved in identifying a replacement, but there has not yet been a breakthrough. Although many manufacturers have started using Chromium (III) as safer alternative for Chromium (VI), performance remains a concern.

- **The dynamic nature of regulation:** Boeing developed boric sulfuric acid anodizing as an alternative for Chromic acid anodizing in 1990 for non-critical parts. But with the addition of boric acid—used as a process substance in boric sulfuric acid anodizing—to the REACH candidate list, the company might again have to seek a replacement, because eventually boric acid can be expected be added to REACH’s authorization list.
- **Supply-chain disruption:** since registration and authorization for a substance is costly process, chemical producers or distributors may cease production or distribution of regulated substance if it does not contribute much to their revenue. According to the Association of European Airlines (AEA), “Due to comprehensive data and analysis requests, approval costs have been estimated at up to €5 million per substance per use. In addition, the ECHA can refuse to grant authorization.”
- **Obsolescence management:** an aircraft lasts for 30-40 years in service and product value creates a business case for airliners for overhaul and repair. Therefore, any material substitution because of regulation will mean major changes to existing fleet or out-of-production aircraft. And changes in approved structures are nearly impossible to implement because the parts are highly integrated and co-dependent.
- **Escalation in maintenance cost for airlines:** due to the restriction of substances, airlines may have to send the component—or in the worst

case, entire aircraft—outside the European Union for even minor repairs. On average, an aircraft sees utilization of 16 hours every day; with potential REACH-related declines in flight utilization, airlines will incur losses.

- **Complex supply chain:** the aviation-industry supply chain can have seven or eight tiers, with negligible interaction between the two extremes of the chain (i.e. a chemical producer and an aircraft integrator). Many of the suppliers in the mid-levels are SMEs without any knowledge of REACH or the capability to implement the regulation. In such scenarios, establishing effective communication throughout the supply chain is significant challenge.

Response by industry

Companies have collaborated and formed groups like IAEG (International Aerospace Environmental Group), CTAC (Chromium Trioxide Authorization Consortium), CCST Consortium Chromium [VI] Compounds for Surface Treatment REACH Authorization Consortium) to work together to mitigate the risks posed by the regulation.

- OEMs have initiated comprehensive analysis of their product portfolios to identify the use of regulated substances in their products and processes.
- Companies have started educating their suppliers regarding the acute impact of the REACH regulations.
- Extensive research is ongoing to find alternatives to some vital processes such as Chromium (VI) plating, cadmium plating and others.

Although the aircraft industry has adopted initiatives to comply with the regulation, considerable effort remains to achieve the goal of REACH compliance. ■



Author: Raj Kishore, Senior Engineer, UTC Aerospace Systems.



Lightweighting: WHAT'S NEXT?

BMW i3



Experts weigh in on the challenges and future enablers in the battle to reduce vehicle mass.

by Lindsay Brooke, Ryan Gehm and Bill Visnic

Are there any automakers who haven't yet put at least one new model through the weight-reduction wringer? Vehicle mass efficiency has joined the vanguard of product development where every gram lost is heralded. And it's no passing fad—escalating global fuel economy and safety regulations ensure that lightweighting, as a product-development tenet, is here to stay.

The list of 2016 vehicles that are lighter than their predecessors continues to grow. It includes such notables as the **Nissan** Altima, which dropped 80 lb (36 kg). **Acura's** TLX is lighter by 55 lb (25 kg). The **Chevrolet** Malibu, part of GM's mass reduction crusade, shed a whopping 300 lb (136 kg) versus the previous car. Experts say a 100-kg (220-lb) reduction in vehicle weight typically brings a 3%-5% reduction in CO₂ emissions, depending on vehicle size and powertrain solutions.

Mazda's new CX-9, a 3-seat unibody SUV, is a shining example of lightweighting driven by holistic design and analysis. Aiming for the quietest cabin in its class, the CX-9 team engineered a thicker-gauge floor pan, added 53 lb (24 kg) of NVH mastics and blankets, more robust door seals and acoustic-laminated glass. But while the pounds were piling on to create the quietest Mazda ever, the powertrain team squeezed 132 lb (60 kg) from the new engine, 56 lb (25 kg) from the all-wheel-drive system and about 100 lb (45 kg) more in other areas.

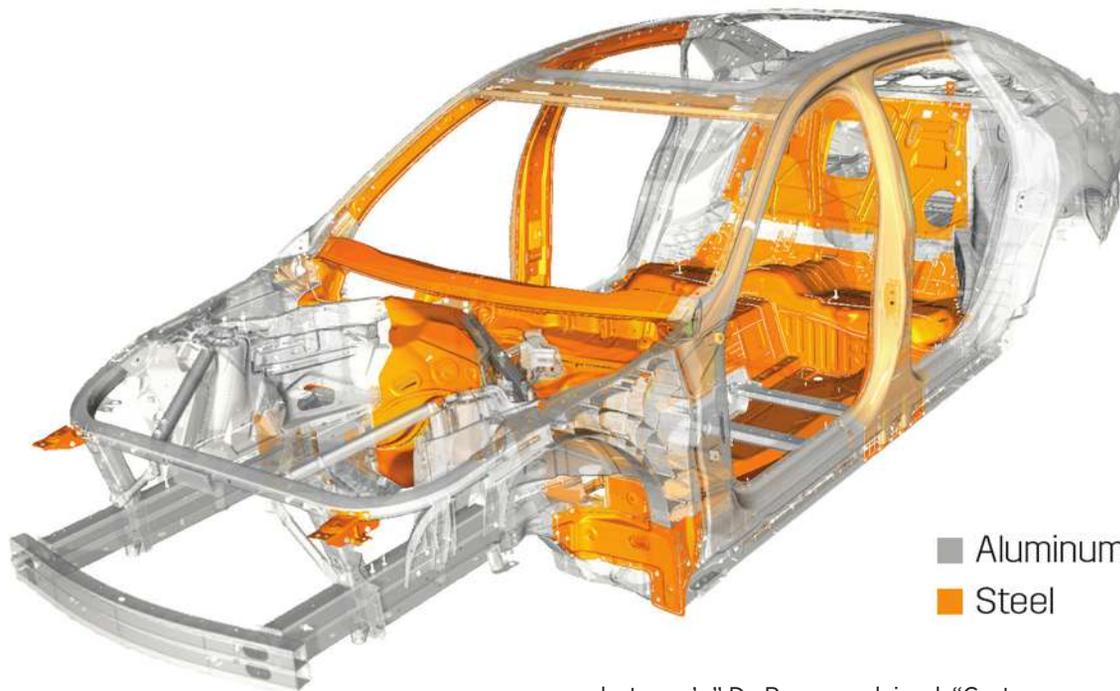
These reductions more than offset the NVH countermeasures, leaving the new CX-9 about 250 lb (113 kg) leaner than the 2015 car.

"The industry has become more aggressive in its lightweighting actions and its rate of introducing the technology is accelerating," observed Jay Baron, Ph.D, President and CEO of the **Center for Automotive Research** (CAR). "The data we've been collecting shows it's gone from an average of about 3% per year to 5% per year, depending on how you want to measure it."

Dr. Baron and other experts note that the supply base has become fully engaged. "The industry's doors are open wider than ever before—if you're a supplier and have a light-weight technology solution, the car companies want to hear about it," Dr. Baron noted.

Vehicle lightweighting "is arguably no less of an important consideration as powertrain selection nowadays," asserted Andrew Fulbrook, **IHS Automotive** Director of Global Powertrain

Lightweighting: WHAT'S NEXT?



The BMW i3 and Cadillac CT6 provide a glimpse into the lightweight mixed-material vehicle future. The electrified i3 (previous page) pushes the current state of the art with its use of CFRP and high aluminum content in the primary structure. The CT6 (left), winner of the 2016 Enlighten Award, optimizes steel and aluminum including beautiful and complex AL nodes cast by Magna's Cosma group.

■ Aluminum
■ Steel

Forecasting. Both technology domains have the ability to provide efficiency gain while maintaining or improving performance and drivability, he said, with lightweighting also offering potential reductions in road load.

Overcoming 'mass creep'

In a recent survey published by CAR on future vehicle-lightweighting trends, industry decision-makers indicated that mixed-materials solutions will predominate over aluminum-intensive programs going forward—a practical strategy driven by cost and by manufacturing considerations such as part formability, dissimilar-material joining and paint-shop capability, commented Dr. Baron.

The CAR respondents echo the views of nearly 20 experts interviewed for this article. Both groups highlighted the nagging challenge facing every lightweighting initiative: How to overcome what Chevy Malibu Chief Engineer Jesse Ortega calls "mass creep"—the weight of added safety, emissions and feature content that can offset the weight saved during base vehicle development. For many vehicle program managers, simply attaining curb-weight parity with the outgoing vehicle is a triumph.

The CAR survey asked, "Between now and 2025 do you feel you need to add weight to the car? And what's forcing you to add it?" Respondents replied that they expect a 5% overall mass gain, split 50-50 (about 2.5% each) between added mass for performance and for safety.

"You can't sell cars that are almost as good as

last year's," Dr. Baron explained. "Customers want the better performance that comes from increased body stiffness, for example, which may come at a price of structural reinforcements and mass. Same with lower NVH—it's a big issue because light materials tend to transmit vibrations more."

His advice: "If you're planning for a vehicle to be 10% lighter, you've got to reduce mass by 15%."

Product planners tell *Mobility Engineering* they're concerned about the capital cost of premium materials—new higher-strength steel and aluminum alloys, carbon-fiber-reinforced plastics (CFRP) and magnesium—and how rising cost will impact vehicle retail price. Veteran industry analyst Mike Robinet, Managing Director at IHS Automotive, talks of an impending "cost cliff" driven by a combination of lightweighting, vehicle electrification, increased demand for advanced driver-assistance systems (ADAS) and connectivity content. And faster product cadences will likely affect cost amortization.

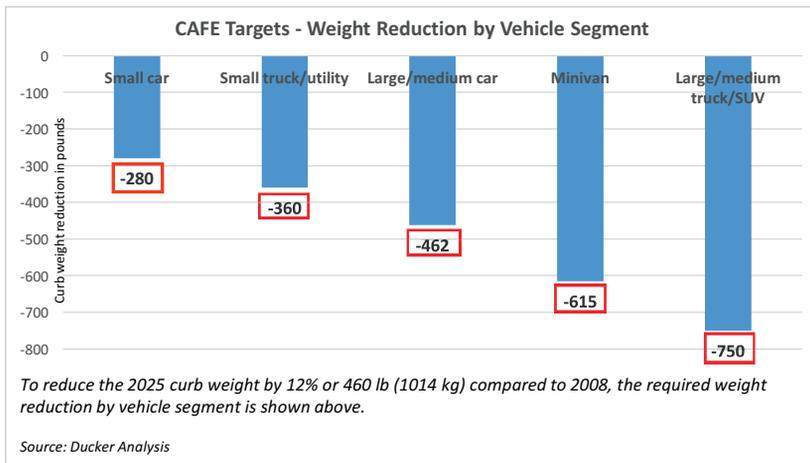
Recent vehicle programs reflect the cost-prudent approach that is expected going forward. GM chose a metals mix for the 2017 Chevrolet Bolt EV. According to Chief Engineer Josh Tavel, the car's underbody consists of 95% high-strength steel or advanced high-strength steel, including some new alloys making their auto-industry debut. Bolt's upper body is 80% HSS.

"The team saved about 50 pounds by using aluminum for the closures," Tavel reports. Another 200-mi (321-km)-range EV with a heavy battery pack, Tesla's "affordable" 2017 Model 3, reportedly also uses mixed-materials construction—the company's first non-aluminum-intensive vehicle.

Lightweighting the pickup truck

Experts believe steel and aluminum will continue to dominate vehicle structures and chassis systems beyond the 2025 timeframe. Stronger and more formable alloys aimed at making lighter components and subassemblies are in the pipeline. Meanwhile structural composites, engineering plastics, and specialty light metals including magnesium will find greater opportunity.

A conversation with Paul Belanger, Director of R&D, Body in White at Gestamp North America, revealed the impact of new alloys and forming technologies. "We worked with Honda R&D on the new [2016] Civic,



Whether or not the mid-term review of U.S. CAFE regulations ends up moderating the 54.5-mpg fuel efficiency target as could be inferred by the July 2016 Technology Assessment Report draft, OEMs continue to work aggressively toward meeting vehicle lightweighting benchmarks for each market segment.

employing hot-formed ultra-high-strength steel (UHSS) for the rear rails. The material properties enabled Honda to reduce complexity of the car's rear structure, improve its kinematics and achieve a 20% weight saving vs. the previous Civic.

He said Gestamp is currently involved with development of a super-strong 2-gigapascal UHSS grade "which will allow even further down-gauging." Industry newcomer **NanoSteel** and partner **AK Steel** are prototyping a new automotive UHSS grade designed to simplify production, enabling the stamping and forming of parts at room temperature, reported CEO Dave Paratore.

The aluminum industry is firing back with new high-strength 7000-series alloys designed to challenge steel's hegemony in impact-critical areas such as B pillars. "We're out to make inroads in those exact areas with higher-strength grades now in development," said Duane Bendzinski, Global Director of Technology, Automotive, at **Novelis**.

Bendzinski notes that the OEMs' urgency to reduce vehicle mass is pushing suppliers to shorten their own development processes. "We're validating new products and getting them into customer evaluation faster for incorporation into new vehicle designs in the upcoming 3-to-6-year window," he said.

The heavy steel ladder frames underpinning most pickup trucks are even a target market for aluminum as future CO₂-driven regulations get tougher. "We think it's more of a design question than a materials one," Bendzinski asserted. "In the not-too-distant future there will be opportunities to take weight out of those heavy ladder frames. It's a primary area for the extrusion folks and it's an opportunity to use roll-formed (aluminum) sheet in large quantities."

Composites' opportunities

BMW's pioneering use of CFRP for the "black bodies" of its electrified i3 and i8 models signaled a serious commitment to bring lightweight composites, long proven in aircraft and racecar structures, into the automotive mainstream, albeit at comparatively low volumes. Carbon fiber's main attraction is its strength-to-weight ratio and the potential for net vehicle weight reductions up to 60% via mass de-compounding, according to ORNL.

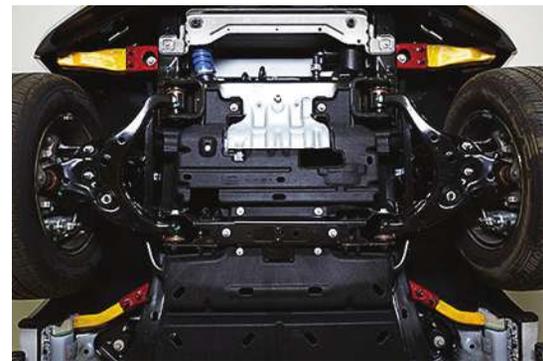
CAR's Dr. Baron believes the structural composites industry "has a whole world of opportunity waiting for it in automotive—but it's going

to have to learn to work together in the steel industry model," he said. "Lack of a robust supply chain will continue to hold them back." He cautioned that the sector's reliance on unique solutions delivered company by company is an impediment.

"If I'm an OEM looking for a new materials solution, I want to be able to buy it from four companies—not just from one," Dr. Baron observed. Steel's commodity-focused product model enables standardized specifications and testing and in some cases, a more rapid entrée into production. There is no analog to DP700 [a dual-phase steel] in the composites world, he opined.

New technology relationships are spreading among the auto industry, government agencies and academia. **Ford Motor Co.** and **DowAksa** recently formed a joint development agreement to create new families of more cost-effective thermoset and thermoplastic CFRP components and take them to the proof-of-concept level. The new JDA is part of the **U.S. Dept. of Energy**-sponsored Institute for Advanced Composites Manufacturing Innovation (IACMI) which aims to commercialize CFRP-related processes.

Another composite, polycarbonate, has long been expected to replace conventional automotive glazing with less mass and other benefits. Ford claims **Corning's** new 'Gorilla Glass' (a thin polycarbonate laminate widely used in mobile devices) used first on the 2017 GT supercar is 30% lighter than conventional glass and is stronger, more durable and optically clearer. Is polycarbonate glazing a lightweight candidate for volume vehicle programs after 2020? Perhaps.



Lightweight vehicle design sometimes gets sideswiped by new test procedures and regulation. Ford's development of the aluminum-body 2015 F-150 was underway when the Insurance Institute of Highway Safety introduced its new small-offset front crash test. To comply, Ford engineers had to retrofit four tubular-steel "Rigid Barrier Countermeasures" (painted yellow/red in this photo) on certain F-Series cab configurations. (IIHS photo)

Lightweighting: WHAT'S NEXT?

Coatings technologies that offer collateral lightweighting benefits as well as friction reduction and NVH attenuation are receiving greater attention by suppliers. A proven example is the liquid acrylic sound-deadening coating (LASD) produced by **Henkel** that's replacing relatively heavy bitumen acoustic mats in critical areas. Henkel claims mass reductions up to 30% for its incumbent low-density LASD which weighs 0.9 to 1.1 g/cm³.

New processes drive future actions

Robust processes to enable lightweight solutions in high-volume automotive manufacturing are at least as important as the materials, most experts agree. "The development of creative, low-cost methods to assemble and join multi-material solutions on existing assembly lines is an imperative," said Dick Schultz, a former **Alcoa** executive and long-time materials analyst at **Ducker Worldwide**.

A process "enabler" with huge future potential is the ability to weld steel with aluminum. GM and Honda are both using new multi-patented innovations in this area, which engineers believe are vital for greater mixed-material construction. GM's spot-welding process is currently underway for the rear seatback frame of the **Cadillac CT6** and is expected to be expanded to the CT6 hood assembly—then to higher-volume applications.

Honda has used Friction Stir Welding since 2012 to join steel to aluminum in vehicle sub-frame production. This was followed by another welding method for joining aluminum outer skins with steel door subframes, first implemented in series production on the 2014 Acura RLX. Using a hem-like double seam filled with adhesive enables the two metal surfaces to be welded with minimal thermal deformation. Honda engineers claim the new welding process helps to reduce door-panel weight by approximately 17% compared to standard steel doors.

Weld bonding pairs spot welding with structural adhesives to increase stiffness and improve crashworthiness, while reducing the number of spot welds. It's a key to future mixed-material vehicle construction. Adhesive suppliers **Aderis Technologies**, **Ashland**, **Atlas Copco**, **Dow Automotive Systems**, **Henkel**, **PPG** and **3M** are in the thick of developing new adhesive-joining solutions. Dow engineer and marketing director Peter Cate noted that parts consolidation through design offers significant weight reduction using CFRP components bonded within "hybrid-material" subassemblies.

Despite the billion-dollar investment by



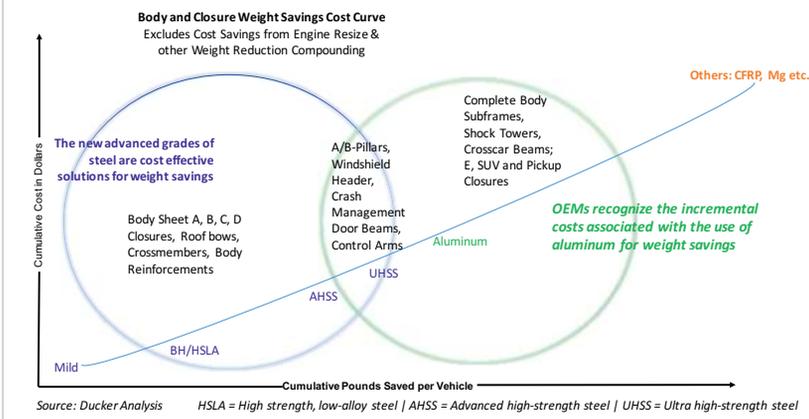
BMW and its material partner **SGL Group** to develop CFRP for series production (see <http://articles.sae.org/8548/>), new innovations are still needed to mitigate the cost of the material's process-intensive fabrication. CFRP composites currently cost about three times more to produce than the \$5/pound the auto industry seeks. **Oak Ridge National Laboratory** and Knoxville, TN-based **RMX Technologies** recently launched co-development of a cold-plasma-based processing technology that has the potential to significantly cut the time and energy required to make affordable CFRP fiber.

The ORNL/RMX technology aims to improve the oxidation stage of carbon-fiber's conversion process. The oxidation process offers a 20% cost reduction versus current commercial methods—but more cost needs to come out. The team is working with German acrylic textile maker **Dralon** on a high-strength fiber that is projected to deliver another 20% cost reduction.

Such progress is good news to Dale Brosius, chief commercialization officer at the **Institute for Advanced Composites Manufacturing Innovation**, an industry-government partnership. In a recent interview with this magazine, he said IACMI's goal is to drive a 25%-50% reduction in CFRP costs within 10 years, while reducing by up to 75% the energy required to produce the material. Brosius conceded that cost and energy-intensive manufacturing are CFRP's chief drawbacks. "We (the CFRP industry) can't be doing things at aerospace rates—we've got to get to automotive rates," he asserted.

Magnesium (Mg) alloy is 30% less dense than aluminum, but its applications tend to be aimed at large components such as cross-car beams and recently the liftgates of the **Lincoln MKT** and **Chrysler Pacifica**. GM is among many OEMs looking for Mg cost-reduction solutions. It has been operating a new vertical squeeze-casting (VSC)

To 2025 and beyond: OEM and Vehicle Segment-Driven Material Choice
Optimizing use of AHSS, aluminum, CFRP and Mg according to the weight savings required



The future automotive materials portfolio will offer greater choices of new lightweight metals and engineered composites tailored to specific vehicle applications.

machine at its China Advanced Technical Center that is designed to more affordably produce magnesium castings.

Designed by teams in Shanghai and Detroit, GM's VSC machine uses high squeeze pressure to improve casting integrity by eliminating oxide inclusions. GM engineers believe the new process will allow magnesium castings to displace certain forged components, reducing a part's overall cost. The machine is sited to leverage the material's availability—China accounts for about 80% of the global magnesium output.

Shultz, the Ducker Worldwide veteran, acknowledged magnesium's potential but underscored its current shortcomings. He said the \$2.50/lb of weight saved with Mg die castings and supply uncertainties "are considered a deal-breaker for most OEMs." However, for OEMs to attain the final 20% of the 500-odd pounds the average vehicle needs to shed to meet 2025 regulations will require "a 3-5% penetration from a combination of magnesium and carbon-fiber reinforced epoxy and SMC composites."

If the OEMs do not do this, "it will be because they are not willing to spend the necessary money on the new plant and equipment to make it happen—not because the materials needed to save a significant amount of weight are unavailable, unproven or too expensive," Schultz said.

The foundry industry has also heeded the lightweighting call. In Europe, 24 steel and forging-industry companies have formed the **Lightweight Forging Initiative** to demonstrate the potential of forged parts to enable lightweight designs versus competing production processes and materials. Phase I studies conducted in 2013-14 determined that advanced steels and forging technologies could reduce light-vehicle mass by up to 42 kg (93 lb), mainly applied to powertrain and chassis components.

Grede, a U.S.-based producer of cast-iron automotive components, is using its experience with thin-wall lost-foam casting as a member of LIFT, a public-private partnership operated by the **American Lightweight Materials Manufacturing Innovation Institute (ALMMII)** that is developing and deploying advanced lightweight solutions. According to Jay Solomond, Vice President, Engineering & Technology, Grede "has completed optimizing the design and chemistry which has resulted in 40% weight reduction and 50% thickness reduction." Trials



As CO₂ regulations become more stringent, every vehicle component becomes a potential candidate for future lightweighting measures. Ford has prototyped forged AL connecting rods, an example of which is shown at right next to a production steel rod. (Lindsay Brooke photo)

on differential-case parts created as part of LIFT have begun.

Solomond told *Mobility Engineering* that through the LIFT process Grede has been using existing production lines and advanced molding techniques. "This means we can make improvements entirely with existing capital and it doesn't require any new equipment," he noted.

How extensive will lightweighting be? Forged aluminum connecting rods investigated by Ford and Honda would offer a 30% weight saving on reciprocating and rotating mass per engine versus today's cast iron or steel rods. Long-term durability remains an issue in automotive use, engineers say.

With all the possibilities offered by lightweighting technologies, what will the construction of post-2025 passenger vehicles consist of? Experts we spoke with pointed to today's BMW i3 and i8, Cadillac CT6, Ford F-Series, Tesla Model S and even the Chevrolet Corvette as directional inspirations for the cars and trucks to come. Opinions were divided on how widespread aluminum-intensive vehicles will be in the 2025-30 timeframe. Most predicted that cost will continue to make mixed-material solutions—incorporating a greater percentage of composites—the reigning choice. Whatever the details, "lightweighting" appears certain to remain a product-development mantra. ■

The Best of COMVEC 2016

Autonomous vehicles and improved fuel efficiency via advanced powertrain solutions are pressing topics detailed in this select group of technical papers from the SAE Commercial Vehicle Engineering Congress.

Phase 2 Program Highlights

- Proposed Phase 2 standards phase in from 2018 to 2027
 - Standards would begin in 2018 for trucks and in 2021 for other categories
 - All standards include incremental in 2024 and new full phase in by 2027
 - Long lead time support for ongoing reliability and durability
- Recognizing the unique nature of the industry, the Phase 2 includes important compliance flexibilities to manufacturers, e.g.,
 - Averaging, banking and trading programs (2017)
 - 1-year delay for small businesses
- Program includes proposed improvements to computer simulation compliance program to recognize new technologies and better reflect real-world driving

A first-of-its-kind special publication highlighting some of the best technical papers from an SAE technical conference has been published by SAE's Commercial Vehicle Product Group. This collection of select papers from the 2016 COMVEC event, developed in partnership with the SAE Journals and Media groups, offers leading industry perspectives on key issues affecting the on- and off-highway industries, with a specific focus on connectivity, the theme of this year's conference.

While the book (<http://books.sae.org/pt-180/>) includes 10 complete technical papers that represent the breadth of the entire technical program, the following special section features condensed versions of three of those papers.

Technology supporting autonomous driving has already impacted the commercial vehicle industry and will continue to do so in the future. Investments in this area have grown rapidly, leaving a wide range of opinions on what the future of autonomous operation will look like. **John Deere** engineers provide their perspective on the topic and how fully autonomous solutions will lead to the optimization of the worksite ecosystem.

The commercial vehicle industry has always been focused on improving efficiency to lower customers' total operating costs, and government regulation has only sharpened the focus on efficiency and emissions. The recently issued

final Phase 2 greenhouse gas (GHG) standards affecting model year 2021-2027 medium- and heavy-duty on-highway vehicles illustrates this point. The U.S. **EPA** and National Highway Traffic Safety Administration (**NHTSA**) expect the new rules to save more than 1 billion metric tons of CO₂ emissions and 2 billion barrels of oil, while also saving vehicle owners \$170 billion in fuel costs, over the life of the program.

The agencies refer to Phase 2 as a "technology-advancing" phase that will require emerging technologies not yet in widespread use. Advanced powertrain solutions such as waste heat recovery, presented as part of a COMVEC session on fuel economy improvement and CO₂ reduction is one area that can help the industry achieve stricter targets.

Fuel consumption and emissions reduction have been two of the primary drivers in recent years of successful application of engine downsizing in the passenger-car and heavy-duty on-highway markets. There has been less activity for off-highway applications, but **FEV** researchers are investigating downsizing to improve fuel economy, reduce purchase price, and provide packaging and machine layout improvement opportunities in off-road machines.

Read on for a deeper dive into these key topics and technologies that are shaping the industry now and into the future. ➔

Optimizing waste heat recovery for long-haul trucks

CNH Industrial and AVL run a demonstrator vehicle with a WHR system to show significantly reduced fuel consumption.

A waste heat recovery (WHR) system for a long-haul truck application was examined via simulation, test bench, and public road vehicle testing as part of a joint project between **CNH Industrial** and **AVL**, with the goal of developing a cost-effective mechanical WHR system for an **Iveco** Stralis Euro VI truck. The WHR system uses exhaust recuperation only and employs up to 110 kW of exhaust waste heat for the organic Rankine cycle (ORC) in a typical European driving cycle.

For on-road truck application, several waste heat sources were available for the ORC at different temperature levels. Based on thermodynamic calculations, production costs, and complexity, along with total cost of ownership evaluation, the decision was made to focus on the high-temperature sources from the vehicle cooling system for the ORC. This enabled a high overall ORC efficiency with a minimum number of heat exchangers.

Based on the temperature levels available in the long-haul truck application and component availability, ethanol was considered to be the best choice for operating fluid due to the highest power output enabling the highest overall efficiency of the complete combustion engine and WHR system. Selection of the EGR (exhaust gas recirculation) heat source was evaluated in terms of costs and benefits, as well as diagnostics implications and safety aspects. For the public road testing efforts beginning in 2015, the use of exhaust heat recuperation only was chosen.

The Euro VI Cursor II engine from **FPT** was selected for testing. The combustion engine and all the WHR components were instrumented and integrated on an Iveco Stralis vehicle frame to conduct test bench activities. The test bed setup of the WHR system is shown in Figure 1. After initial operation and controller optimization, the complete system was optimized for stationary and transient operation, focusing on typical European real-life driving cycles.

After successfully optimizing the WHR system on the test bed, the WHR system was integrated in the vehicle, as depicted in Figure 2. Vehicle tests were performed on public roads in Austria with the target of testing and calibrating the WHR system for a wide range of relevant operating conditions.

Simulation models supported the WHR development throughout the project, from the paper phase until final testing on the public roads. They provided useful input for working fluid selection, component sizing, control strategies development, and prediction of fuel consumption results under several operating conditions.

The vehicle testing and simulation showed the following results:

- 2.5% BSFC reduction for a European real-life cycle with 108 kW
- 3.1% BSFC reduction for a U.S. real-life cycle with 143 kW
- 3.4% BSFC reduction for a RMC with 182 kW
- Up to 6.5 g/kW·h BSFC reduction in the engine map.

All results were obtained with WHR prototype stage 2015 parts. The 3.4% brake specific fuel consumption (BSFC) reduction for the ramped-modal cycle (RMC) fits well to the EPA technology assessment claiming



Figure 1. Test bed setup using vehicle frame.



Figure 2. WHR system vehicle integration.

a 3.6% fuel consumption reduction potential for WHR in 2020.

Up to 3.5% BSFC reduction for the European real-life cycle is assumed as the parts mature toward series production. With this assumption, a BSFC reduction above 4% is expected for the higher powered U.S. cycles.

The research also included a possible technology roadmap containing WHR as a central part to achieve a future CARB BSFC target value of approximately 172 g/kW·h. WHR combined with other thermodynamics measures—including advanced turbocharger technologies, alternative EGR concepts, optimal compact combustion along with friction optimization—can possibly make this happen. ■

Based on SAE technical paper 2016-01-8057 by Michael Glensvig, Heimo Schreier, Mauro Tizianel, and Helmut Theissl of AVL List GmbH; Peter Krähenbühl and Fabio Cococchetta of FPT Motorenforschung AG; and Ivan Calaon of Iveco.

Autonomous solutions in agriculture

Deere advances autonomous driving and machine system automation to increase productivity and convenience in farm production.

Advances in vehicle electronics and satellite navigation technologies have resulted in automatic guidance systems in agriculture that enable increased productivity and convenience. Systems such as **John Deere's** AutoTrac provide closed-loop control of a vehicle to a straight line or curved path via steering control. Electrohydraulic controllers provide steer-by-wire integration with the vehicle. Key components of these systems include a global positioning satellite (GPS) receiver, a method of steering actuation and a user interface.

Automatic guidance systems increase productivity through accurate operation at higher speeds for most tasks, and by providing the ability to perform night operations. Other benefits of these systems include reducing the skill level needed and the human fatigue experienced in operating the machine.

The level of precision needed to perform agricultural operations depends on the task. It ranges from meter-level precision of GPS for mapping of information such as harvest data, decimeter-level accuracy for guidance for tillage and spraying, and centimeter levels of control to manage the needs of each plant. Fusion of sensor information provides further accuracy: sensors are used to detect the cut-uncut edge of the crop as well as mechanical feelers or advanced noncontact methods such as perception sensing with cameras or lidar.

Agricultural vehicle guidance requires consideration of the kinematics of the vehicle system, the pose of the vehicle regarding the terrain, and the position of the vehicle with respect to growing crops. The lever-arm effect experienced by the GPS receiver is compensated by sensor fusion

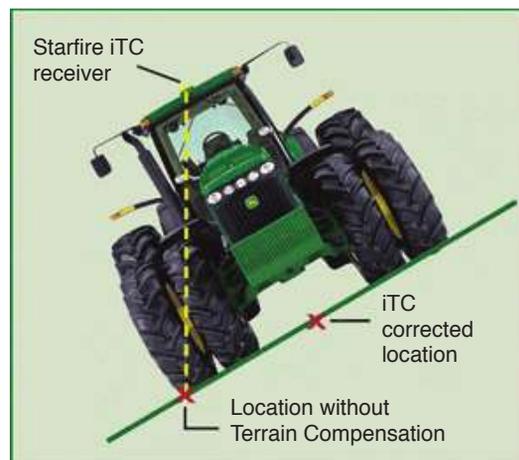


Figure 1. Lever-arm correction of the GPS sensor is compensated using sensor fusion with an IMU-sensor that can be integrated into the GNSS.

with an inertial measurement unit (IMU) that measures the pose so it can be corrected geometrically. Figure 1 shows lever-arm correction of the GPS sensor through sensor fusion.

The advances in automatic guidance have combined with other technology advances such as access to information and other forms of machine system automation to enable



Figure 2. MachineSync leverages GNSS technology on two machine systems to coordinate machine operations during a work task.

machine system productivity. Advances include automation of machine functions, coordination of machine-to-machine operations, and increased levels of machine system automation.

Communications between vehicles and from the vehicle to data storage and management systems is expanding productivity by allowing information to be documented more accurately and quickly and enabling coordination between vehicles and information from season to season.

Telematics, which provides communication from the vehicle to an office, gives information on the use of the machine system and allows the farmer to make decisions that will improve productivity.

Communication between machines enables the coordination of activities on machines, resulting in increased performance.

MachineSync, shown in Figure 2, uses Global Navigation Satellite System (GNSS) technology on two machine systems to coordinate machine operations between a combine and a tractor-grain cart so that unloading can occur while the systems move through the field.

Machine systems can also be optimized by systems that generate machine path plans across the landscape. In this way, the guidance pattern can be optimized as the machine traverses a field. Machine operations can be integrated with

these plans to manage the vehicle/implement actions according to location within the path plan.

All of these technologies are part of a progression of increasing the machine productivity of human-machine systems. However, the system focus around the machine can only partially achieve the productivity optimization across the production system and worksite. Expanding the focus to the worksite ecosystem will further improve productivity and convenience.

Integrated worksite solutions are the next generation of tools to increase agricultural productivity. They enable increased machine systems automation, optimization of various interacting systems, including ergonomic performance, and optimization of the worksite through information management and decision support. These solutions consist of products and services for the worksites that also interact with the broader industrial ecosystem. Applications include management of inputs such as seed and fertilizer, and outputs such as crop yield.

Other sources of autonomy in production systems include automating discrete machine-systems, automating the data infrastructure used to manage the worksite, and modular approaches to autonomous systems that conduct clean-sheet redesign of the machines and tasks required. Beyond machine autonomy, robust communication in the field and data infrastructure is required for the development of sophisticated autonomous systems and can also benefit manned operations.

Innovations in machine systems automation continue to increase productivity and convenience in farm production. These innovations will progress into integrated worksite solutions, which will transform agriculture production systems. ■

Based on SAE technical paper 2016-01-8006 by John Reid, Stewart Moorehead, and Julian Sanchez of Deere & Company; and Alex Foessel of John Deere Brasil SA.

Downsizing a HD diesel engine for off-highway applications

FEV examines four technology paths to downsize a six-cylinder 7.5-L diesel to a four-cylinder 5.0-L while maintaining performance.

Many off-highway applications demand a relatively high low-end torque compared to on-highway applications. Because of this, applying downsizing strategies for non-road applications while meeting the operational requirements of the machine can be challenging. Still, downsizing can result in efficiency improvements as well as reduced production costs and packaging benefits.

Certain applications in the off-highway market are suited for engine downsizing. One example is a midsize tractor (Figure 1), which can be used for heavy field work that requires the engine to operate at medium to high speeds with a high load factor, and ancillary farm activities that are transient and for which the engine is concentrated toward low to medium engine speeds.

Various engine and aftertreatment configurations can be applied to meet Tier 4 Final emissions standards. The most common component used in all configurations is the selective catalytic reduction (SCR) catalyst for nitrogen oxide (NOx) reduction. Most applications do not apply a diesel particulate filter (DPF) and rely primarily on low particulate matter (PM) combustion systems to meet Tier 4 Final PM emission levels.

FEV researchers conducted a study to understand the challenges of downsizing a diesel engine from a six-cylinder 7.5-L to a

four-cylinder 5.0-L while maintaining performance. They pursued four technology paths. First, an electrically assisted compressor was used in series with a single-stage mono scroll turbine. The single-stage turbocharger was optimized for the peak power operating point, and the E-booster was used to achieve the low-end torque targets. Three different charge air cooler (CAC) placements were analyzed. The best brake specific fuel consumption (BSFC) was obtained with use of two CACs: one placed downstream of the E-booster and the other downstream of the single-stage compressor.

In a second technology path, an asymmetric twin scroll turbocharger was applied to the downsized engine. This application was useful in increasing the low-end torque beyond that possible with a mono scroll turbine, but it did not meet baseline targets.

In a third path, a two-stage turbocharger was mated to the downsized engine (see Figure 2). In this configuration, two air system layouts were analyzed. In the first layout, both



Figure 1. Certain applications in the off-highway market are suited for engine downsizing: a midsize tractor is one example.

turbochargers were sized to be active across the complete load range. In the second layout, the high-pressure turbocharger was sized to achieve the low-end targets, while the low-pressure turbocharger was sized for optimal operation at the higher speed points. This two-stage sequential turbocharging layout showed better BSFC from the peak torque to peak power operating speeds when compared to a conventional single-stage configuration.

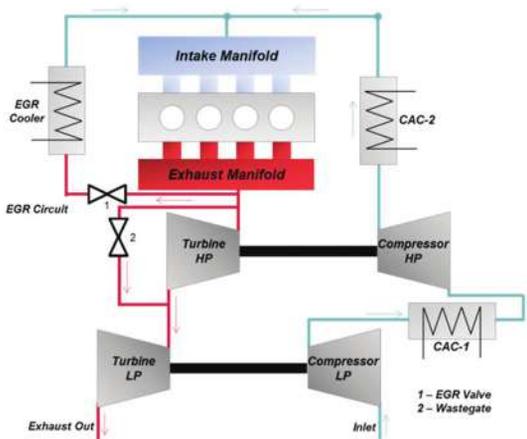
In the final technology path, variable valve timing and actuation were used to increase the turbine power at lower engine speeds. To achieve the low-end torque targets while minimizing the engine pumping mean effective pressure (PMEP), the exhaust timing and lift, along with intake valve timing, had to be optimized at each engine speed. The final configuration consisted of a VVA setup on the exhaust valves and a VVT setup for the intake valves to apply optimum valve timings and durations from 600 rpm to 1400 rpm.

When comparing the best-performing case for each technology that achieved the torque, lambda, and EGR targets, two-stage sequential turbocharging was found to have the best BSFC across the complete full load curve, along with the lowest heat rejection to the cooling system. The E-booster configuration performed similarly. For the two-stage sequential turbocharging layout, the BSFC improvement at the peak power point was approximately 6.8%, while the heat rejection reduced by approximately 5.9%. The two-stage sequential turbocharging layout also improved transient performance and delivered better cycle averaged fuel consumption when applied to the two midsize tractor operating profiles.

Results showed that the most effective technology to downsize a turbocharged diesel engine is to add an additional compressor stage, whether in the form of a conventional turbocharger or an electrically assisted compressor. Further investigations are needed to evaluate options to manage peak cylinder pressure requirements, perform cost and packaging studies, evaluate overall system control complexity, and examine the emissions and aftertreatment system sizing based on peak BMEP levels. Ultimately, the transient capability of the selected air path system must be considered and evaluated relative to the required engine performance. ■

Based on SAE technical paper 2016-01-8058 by Mufaddel Dahodwala, Satyum Joshi, Hari Krishnamoorthy, Erik W. Koehler, and Michael Franke of FEV NA.

Layout A – Two-stage turbocharging with high-pressure wastegate



Layout B – Two-stage sequential turbocharging

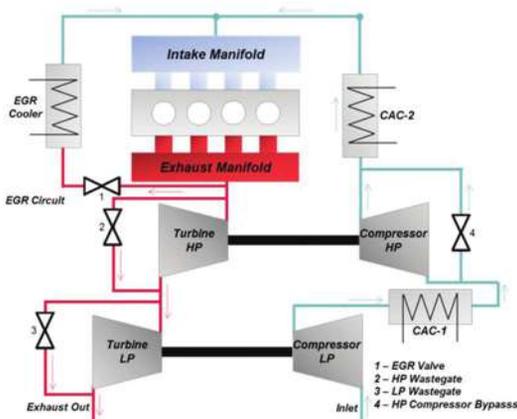


Figure 2. Downsized four-cylinder engine schematics with two-stage turbocharging.



Figure 1.
Boeing Demonstrator
Hybrid Fuel Cell-Battery
Electric Aircraft.
(Image courtesy
Thomas Koehler)

Zero-Emissions Electric Aircraft

**theory
vs
reality**

Many different electrically propelled aircraft have been or are soon to be flying. Recently, a zero-emissions electric aircraft, Solar Impulse, flew around the world with zero fuel. However, an electric aircraft with the payload and range of a B-777 and having zero-emissions is a few more decades in the future.

The electrically propelled aircraft, E-747, discussed in this article will have zero-emissions. E-747 was selected as identification for this study; obviously E is for electrical and the 747 is for the reference aircraft B-747. E-747 will have the same payload and range as a B-747 but with zero emissions. The schedule for such an aircraft to enter service would be about 2050.

Examples of electric aircraft

From an array of electric aircraft flying today, two examples have been selected for subsequent discussion.

In 2008, the world's first cruising flight of an aircraft powered only with a fuel cell occurred with the **Boeing** Demonstrator Hybrid Fuel Cell-Battery Electric Aircraft (Figure 1). To have the power for take-off and climb, the combined output of a battery with the fuel cell is needed. Cruise power, which is significantly lower, is supplied by the fuel cell only. Now scale the aircraft by a factor of 25, and passengers and cargo can be flown across continents and/or oceans. It is not that easy, however.

Antares H2 (Figure 2) is emission free except for contrails. It's first flight was in 2009. The DC motor is directly connected to the fuel cell with maximum voltage of 400 V. Cruise power is about 10 kW giving a range of 750 km. The Antares H2 is a flying laboratory with hydrogen stored in a pressurized tank.

Emissions-free flight: nuclear

In an ideal world, nuclear power offers zero-emissions transportation. The concept of using nuclear power to have emissions-free aircraft propulsion is very alluring. In the 1950's and 1960's, the allure of aircraft nuclear propulsion, ANP, was not emissions but unlimited range. In this time era, the USAF conducted R & D on ANP and concluded the idea was not feasible. Even if the idea yielded a tempting design, public opinion hardened; the public would not allow nuclear reactors flying overhead.

Emissions-free flight: electrochemistry

Combustion, along with steam, launched the industrial revolution and has sustained the revolution for more than 200 years. Combustion yields the quantity being sought—namely heat—yet sets off an uncontrolled scrambling of molecules. Combustion may be uncontrolled, but is not random for the details of physical chemistry are precisely followed. Although engineers can fine tune combustion, output molecules cannot fully be controlled.

On the other hand, fuel cells offer superior control of the output molecules and avoid the apparent random scrambling of molecules. In contrast to combustion, electrochemistry is really cool. Really cool is an expression used by the vocabulary-limited to express enthusiastic support. Really cool also is physically correct so that nitrogen from the air passes through the fuel cell unchanged. Further, with electrochemistry, the Carnot efficiency is sidestepped.

The NASA N3 + X can be more accurately described from the emissions viewpoint as a combustion-electrical aircraft. Combustion precludes zero emissions. The E-747 discussed here is an electrochemistry-electrical aircraft enabling zero emissions.

Emissions-free flight: electrical

A major driver for R & D in electric propulsion is greatly reduced or zero emissions.

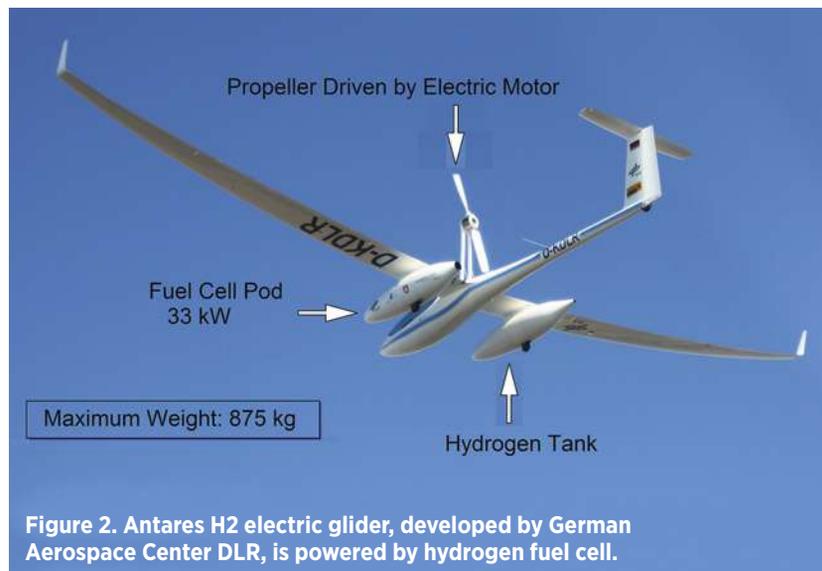
Implementation has already begun with numerous small electric-powered aircraft, and the Solar Image mentioned earlier. For large commercial and business aircraft, much lengthy R & D is needed. Begin by sorting today's technology to find possible avenues to success. Superconducting motor/generators (M/G) almost assuredly will play a major role. Superconducting M/G are soon to drive ships.

Additional electrical technology to be sorted includes solar cells, ultracapacitors, batteries and fuel cells. For the latter three, electrochemistry is the dominant science. The critical design issue is aircraft range. Devices which store energy are unlikely to have the specific energy (Joule/kg) necessary to give the desired range. That fact reduces the choice to one technology—the fuel cell—which has a fuel, namely hydrogen.

Table 1 provides information concerning weight and volume for two fuels and a Li-Ion battery. A particular aircraft fueled by jet fuel has a 10,000 km range. The aircraft has a

	Jet Fuel	Hydrogen Gas*	Hydrogen Liquid	Battery Li-Ion
Specific Energy, MJ/kg	46	142	142	0.89**
Energy Density, MJ/L	37.4	5.6	8.4	-
Range, km	10,000	30,900		200
* Compressed to 700 bar				
** Projected by NASA to 1.8 by 2025				

Table 1. Power source comparison.



certain weight fraction devoted to fuel; the other weight fractions are airframe and payload. If hydrogen were substituted for the fuel using the same weight fraction, the range jumps to 30,900 km. However, the substitution ignores fuel-tank volume. Likewise, if batteries are substituted for jet fuel using the same weight fraction, the range is only 200 km. By 2025 the range may jump to 400 km. Stored electrical energy will fail to yield the required range capability.

Hydrogen as a fuel

Use of hydrogen in an aircraft requires complete redesign of the fuel systems including tanks, pumps, fire protection, monitoring, etc. Hydrogen has a high specific energy (Joule/kg); this fact is favorable. Compared to jet fuel, for the same energy, the mass of hydrogen fuel is about 32%. Hydrogen has a very low energy per volume, which is energy density. The value depends on the method of storage. If highly compressed gaseous hydrogen is used, the fuel tanks must be about 5 times larger than the jet fuel tanks. If liquid hydrogen is used, for identical energy content, the hydrogen fuel tanks must be about 3.2 times larger than tanks filled with jet fuel. Depending on the hydrocarbons, the mass density of jet fuel is about 0.8 kg/L. At the critical point, the mass density of liquid hydrogen is 0.081 kg/L.

Think Super Guppy aircraft. That might be the shape of a large

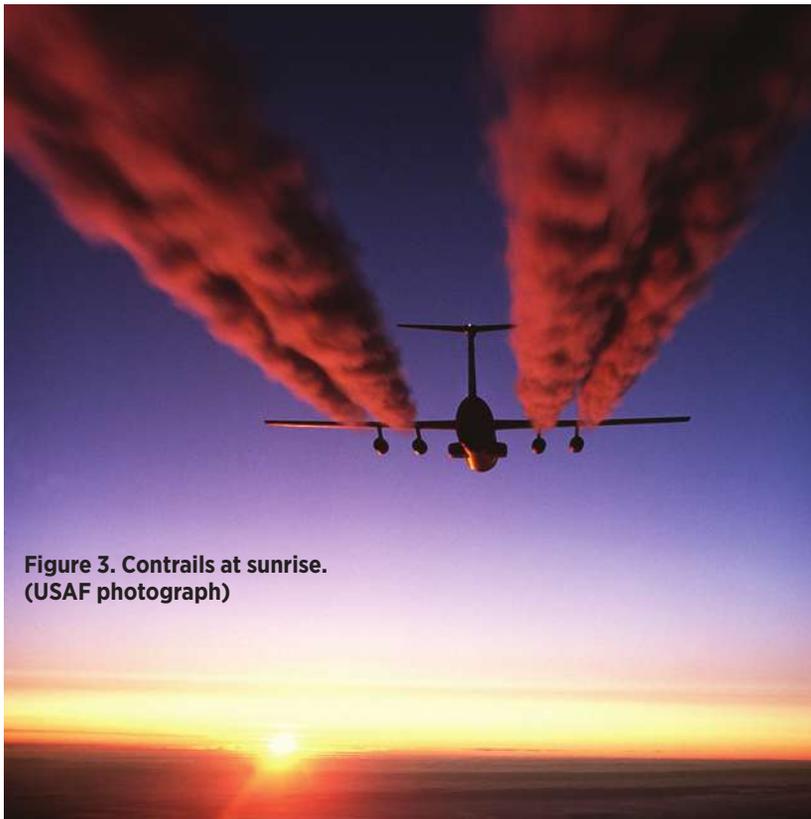


Figure 3. Contrails at sunrise. (USAF photograph)

electrically propelled aircraft using hydrogen with fuel cells. Cruising at Mach 0.85 is not possible. The need for another design approach to accommodate hydrogen is obvious.

The B-747 Series 300 has fuel capacity of 52,410 gallons which is 356,000 lbs. The hydrogen fuel necessary to yield the same energy would be only 132,000 lbs. If compressed hydrogen gas is used, the volume for the fuel jumps to 262,000 gallons. If liquid hydrogen is used, the volume jumps to about 168,000 gallons.

Tempting detour

On the road to the fuel cell-powered electric aircraft, a tempting detour cannot be ignored. Why not just substitute hydrogen for jet fuel? Almost all emissions problems are solved with only a small fraction of the effort to make the all-electric aircraft. Turbofans can be altered to burn hydrogen with minimal effort. Certainly the carbon dioxide problem in the aircraft exhaust vanishes. The various obnoxious oxides of nitrogen remain but might be reduced by fine tuning the combustion. Water in the contrail may increase; this high-altitude water injection is detrimental to climate change. Contrails at high altitude form thin, ice-crystal, cirrus clouds which allow sunlight to pass inward towards the earth but block outward going infrared radiation from the earth. Hence contrails have a warming effect. Search the Internet for “the contrail effect NOVA” for more details.

Because of both NOx and contrails, direct substitution of hydrogen combustion for jet fuel seems a bad idea, even if it is relatively easy.

Storage of liquid hydrogen uses spherical tanks which give minimum heat transfer surface area for the volume of the fluid stored. The storage tank dimensions are based on the analysis shown here. The key equation is

$$E = \frac{WR}{(L/D)}$$

where:

E = energy required to fly the range (MJ)

W = aircraft takeoff weight (kg)

R = range (meters)

L = lift (Newtons)

D = drag (Newtons)

When E is known, the mass of hydrogen is obtained from the specific energy, 142 MJ/kg. Using the density for liquid hydrogen, the volume of liquid hydrogen is found. Knowing the volume, the size of the tanks is determined. The size is shown in Figure 4 which is reasonable for the B-747 size aircraft. In addition, the fuel mass fraction of the overall aircraft weight allows a tankage factor, or gravimetric density, of 4 (kg tank)/(kg hydrogen).

The fuel-cell alternative

Fuel cells have a long history of success in critical missions. The electrical power for the Apollo Project to the moon and home again was by fuel cells. On the road, numerous electric vehicles (EV) powered by fuel cells have accumulated millions of miles of reliable service. The main hurdle for the fuel cell powered aircraft is not the fuel cell but the hydrogen storage. Fuel cell powered submarines are operating reliably in several navies today. These are high-power systems indicating the available mature technology for aircraft. One difference is that the submarine fuel cells use pure oxygen and hydrogen. Aircraft will operate with air plus hydrogen.

For the fuel cell electric aircraft, is a hybrid version desirable? The answer is likely to be yes. Consider a fuel cell and battery hybrid. As is done in the automobile world, a non-dimensional hybridness ratio, H, is defined. For the electric aircraft, the ratio is defined as

$$H = \frac{\text{(battery energy)}}{\text{(battery energy)} + \text{(hydrogen energy)}}$$

Obviously other definitions for H are possible. Here energy was selected because of the close connection with range. When H = 0, the aircraft is pure fuel cell powered and is not a hybrid. When H = 1.0, the aircraft is pure battery powered and is not a hybrid. For 0 < H < 1, the aircraft is a hybrid. The aircraft can be optimized as a function of H.

Symbols can be introduced for energy in the definition for hybridness, H. The resulting equation can be rearranged to yield:

$$H = \frac{1}{1 + \frac{S_H M_H}{S_B M_B}}$$

Zero-Emissions Electric Aircraft

theory vs reality

where:

S = specific energy from Table 1 (MJ/kg)

M = mass (kg)

Subscript H is for hydrogen, and subscript B is for battery. From the equation when $MB = MH$, $H = 0.0125$. When $MB = 2MH$, $H = 0.0247$. Large battery mass gives tiny values of H. This fact is due to the large difference in $SH = 142$ and $SB = 1.8$.

Large battery mass contributes very little to system energy. Stated another way, batteries can never provide significant energy for a hybrid system using fuel cells. However, batteries can provide a surge of power when needed such as during take-off. Energy is needed for range; power is needed for take-off and climb.

The supersonic Concorde needed afterburners to take-off from a runway of reasonable length. View batteries as an afterburner for a hybrid electrical aircraft.

Several different hybrid electric aircraft can be conceived. A Laser-Fuel Cell hybrid may offer advantages and merits study.

Rube Goldberg contraption, innovation or science fiction

A Rube Goldberg contraption is an overly-complex device which accomplishes a simple task. Although the search for new approaches to electric propulsion may incubate Rube Goldberg contraptions, the effort may also open the door to a new era. Here are four samples of thinking “outside the box” to use a cliché:

- Long term storage of photons – not electrons – speculative.
- Hydrogen production from artificial photosynthesis.
- Microwave energy beamed from orbit directly to aircraft in-flight.
- Network of ground-based, globally-distributed, laser beams sending power to individual aircraft.

Synergy for the big two A's: aviation and automobiles

The NASA SUGAR Volt is a “flying Prius.” Prius shines during the city segment of the EPA Driving Cycle. During the highway segment, Prius is essentially an ordinary car hauling a battery. Now think of the flight profile—or the flight cycle in EPA language—for a passenger aircraft. During most of the flight, the “flying Prius” aircraft is operating in the airway cruise mode, and the hybrid is essentially an ordinary aircraft hauling a battery. The greater the range,

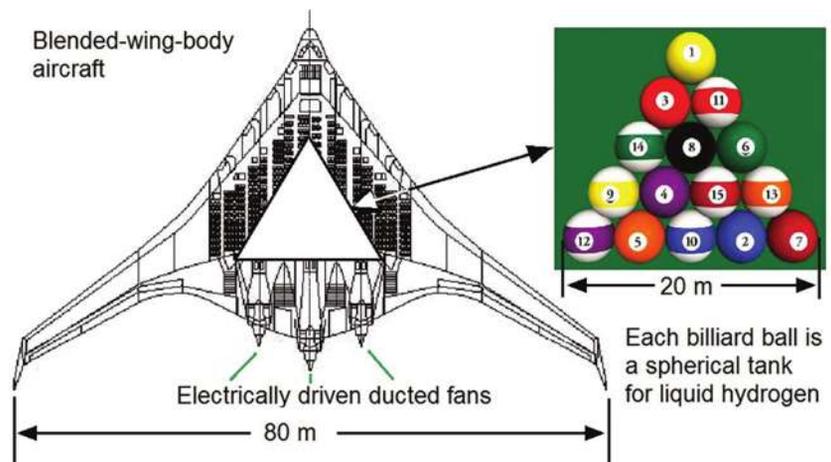


Figure 4. Tank farm for storing liquid hydrogen. Geometry based on racked billiard balls.

the less beneficial the hybrid design becomes. Years ago airlines on both the East and West Coasts offered commuter flights. The commuter aircraft, or regional jet, is a niche for a “flying Prius.”

Using the published specifications for a Prius, the hybridness, H, can be calculated. The value is somewhere about 50%. The optimum value of H for a “flying Prius” will be significantly less. Note that the optimum H for Prius depends on the EPA driving cycle.

Extensive Federal funds are being spent to electrify the automobile. Funds include both R & D for supporting technologies and generous subsidies. The pollution from aviation is minuscule compared with the 1,000,000,000 cars on the road globally. Should the electrification of general aviation be included under the existing funding umbrella? Should the large, emissions-free, electric aircraft be included? Table 2 shows the overlap of and differences between electric automobiles and general aviation. The Boeing Demonstrator, shown in Figure 1, is an actual hybrid fuel cell-battery aircraft offering zero emissions.

Composites, paint and solar cells

Composite materials degrade in UV light. The intensity of UV radiation increases with altitude. Aircraft built using composite materials exposed to UV must be painted to extend the life of the airframe.

Paint increases the weight of an aircraft. According to Boeing, to fully paint a B-747, aircraft weight is increased by 555 pounds (252 kg). Full paint includes upper and lower half of fuselage and tail plus customer markings.

Presently, solar cells provide 300 watts per kg in full sunshine. Suppose a paint-on solar cell that provides both electrical power and UV protection were developed. Would this new invention offer any benefit to an electrically powered aircraft? The approximate solar power for a B-747 painted in solar cells would be

$$(0.3)(252 \text{ kg})(300\text{W/kg}) = 23 \text{ kW}$$

The factor of 0.3 accounts for the cosine factor and surfaces in the shade. At cruise, the B-747 power is about 20 MW. Hence, the solar cells provide 0.12% of cruise power under favorable conditions. If the solar cell output per unit mass could be increased by a factor of 10, then painted-on solar cells become attractive. In this case, a hybrid electrical aircraft becomes a Tribid. Tribid is fuel cells, batteries, and solar cells.

Type	Example	General Aviation, GA, Analog
BEV	Tesla, GM Bolt	Design: $H = 1$. Battery severely limits range. On internet see Airbus E-Fan 2.0.
HEV	Prius	Possible but replace gasoline with diesel. Optimum hybridness, H , different. On internet see NASA Boeing SUGAR Volt.
PHEV	Prius, GM Volt	Possible; larger battery helpful for take-off.
Fuel Cell	Honda Clarity	Design: $H = 0$ acceptable for automobiles. Design: $H = 0$ not quite optimum for aviation. On internet see DLR Antares H2.
Hybrid Fuel Cell-Battery	None	Best choice for general aviation. Optimum H in range $0 < H < 1$. Different optimum H for autos & GA.

Table 2. Correlation between electric automobiles and general aviation.

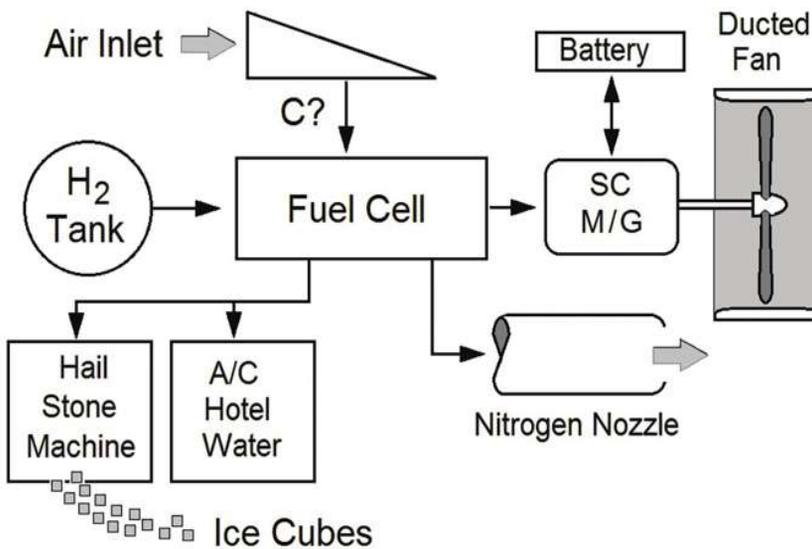


Figure 5. Block diagram showing all components for a hybrid fuel cell-battery electric aircraft.

Special features of fuel-cell electric aircraft

Figure 5 is a block diagram for a hybrid fuel cell-battery electric aircraft. For every kilogram of hydrogen consumed, 36 kg of air is needed. This assumes 100% usage of the oxygen; lower percentage usage means more air. Also, for every kilogram of hydrogen consumed, 9 kg of water is produced.

Inputs to the fuel cell are air and hydrogen. The C? is a symbol to ask the question if an air compressor is needed so that the fuel cell can operate at a fixed pressure. Pressure varies widely with flight speed and altitude. The compressor likely is needed. Besides DC electricity, two other outputs from the fuel cell are water and unused nitrogen. The air inlet causes ram drag. The nitrogen nozzle reduces some of the ram drag penalty by creating thrust.

Not shown is an inverter between the fuel cell and the superconducting, SC, motor/generator (M/G). In motor mode, the M/G drives the ducted fan. During aircraft descent in generator mode, the M/G charges the battery while the fan acts as a wind turbine.

Combustion yields steam; elimination of steam to avoid contrails is an intractable problem. Fuel cells produce water; disposal of water is an imminently tractable problem. Contrails are to be shunned because of warming effects. The water produced by the fuel cell cannot be accumulated, and it cannot simply be dumped overboard, thereby creating a contrail.

The hailstone machine operates similar to the ice cube dispenser on your refrigerator. The ice cubes fall from the aircraft and melt before hitting the ground. Continuously functioning software predicts ice cube trajectory and melting based on real time meteorological information. Based on the meteorological data, the size of ice cubes can be adjusted. Also, the ice cube flow is monitored to avoid hitting other aircraft; awareness of aircraft traffic avoids ice cube collision.

In the event ice cubes cannot be safely ejected, a back-up exists: eject liquid water, which unfortunately creates a contrail. To soothe environmentalists, this situation is anticipated to be infrequent.

With the correct vertical atmospheric temperature and humidity profiles, an electric aircraft flying at 30,000 feet can make a contrail at perhaps 12,000 feet. The cumulus cloud-type contrail is caused by the melting ice cubes and seems to originate due to an invisible aircraft. The contrail has water droplets. Cumulus clouds reflect sunlight and have a net cooling effect.

Summary

Think energy and energy conversion. Apply the aviation filter. Options narrow quickly to combustion and electrochemistry. The heat of combustion moves objects but is also the source of uncontrolled emissions. A combustion-electric aircraft can never be emission free. On the other hand, electrochemistry is largely controlled. Specifically, the success of the totally emission free electrical aircraft depends on:

- Greenhouse gases eliminated by the choice of fuel - hydrogen.
- Oxides of nitrogen eliminated by staying cool with electrochemistry.
- Contrails eliminated by freezing excess water.

The overwhelming key technologies to be conquered are hydrogen infrastructure and hydrogen storage on board aircraft. ■

This article was written by Dr. Allen E. Fuhs, SAE Fellow (Carmel, CA). For more information, visit <http://info.hotims.com/61064-502>.

Global VEHICLES

Aero-slick Land Rover Discovery sheds 1058 lb, gains features

JaguarLandRover engineers continue to achieve significant vehicle mass reductions, this time with the new generation Land Rover Discovery. Shifting to aluminum construction for the body-shell instead of steel and complemented by an intensive lightweighting program for the whole car, has yielded a remarkable 480 kg (1058 lb) saved compared with the previous model. This exceeds even the 420 kg (925 lb) reduction of the **Range Rover** in 2012 when it was switched to an aluminum-intensive architecture.

The new Discovery, revealed at the 2016 Paris Motor Show closely echoes the Discovery Vision Concept which debuted at the 2014 New York Auto Show. For the production car, Land Rover has abandoned a steel body on a steel frame for an aluminum monocoque.

"The (weight-reduction) figure of 480 kg may sound almost incredible, but we have checked it out many times!" said Alex Heslop, Chief Program Engineer. "And the Cd for the new car is 0.33 compared to 0.40 for the previous Discovery." The combination of weight shedding and efficient aerodynamics help deliver improved performance and reduced emissions.



A claimed wading depth capability of 500 mm improves by 200 mm over the previous Discovery's fording capability.

Single-piece bodysides

The new monocoque also allowed what he described as "a versatile, spacious seating solution (for seven 1.95-percentile adults) like no other." Seats are configurable from a smartphone as part of what Land Rover claims as a "world first" remote Intelligent Seat Fold solution—a vehicle occupant could change the seat layout while in a store buying a bulky item.

Those seats are also part of the weight-saving achievement, using lightweight high-strength steel (HSS).

Extensive use of high-strength aluminum alloy has been incorporated within the crash structure. The whole bodyside of the car is stamped as a single panel to reduce joint count and improve rigidity, and the underside of the Discovery is also stamped from a single aluminum blank to enhance structural integrity.

Of the total monocoque, 85% is aluminum, with 43% of that recycled. Simplified exhaust and driveline systems also save weight and magnesium is used for the instrument panel cross-beam, a now-common application for the material. Across the Discovery range, best unladen weight is 2115 kg (4662 lb), the company claims. Luggage space is a maximum 2406 L (85 ft³).

Connection capability includes nine USB ports, four 12-V charge points and a 3G WiFi hotspot for eight devices.

Tough test regime

Heslop emphasized that the car is as good or better off-road as the previous Discovery and has a wading-depth capability of 500 mm (20 in, increased by 200 mm/8 in), which he said is close to flotation point!

Combining both tough-terrain ability and fine ride quality is a salient aspect of all Land Rover products. The new car has "optimized" steel front and rear subframes to meet stiffness and steering-response and chassis-refinement requirements.



Clear visual cues link the new Discovery to other Land Rover models.



Virtual testing of the 7-seat Land Rover Discovery included sand dune impact.



Driving position of the new Land Rover Discovery sees switches minimized, ergonomics improved.

Suspension is fully independent with wide-space double wishbones at the front; the multi-link configuration at the rear also has an integral link to deliver stiffer damping without decaying comfort or impact absorption performance.

Air suspension is an option, lowering the car 60 mm (2.4 in) for easier loading or raising it 75 mm (3 in) for very rough terrain driving. Regular ground clearance is 283 mm (11 in, an increase of 43 mm/1.7 in), approach angle 34°, break-over angle 27.5°, departure angle 30°.

Engine line-up includes a 177-kW (237-hp) version of JLR's Ingenium 4-cylinder diesel delivering a claimed 500 N·m (369 lb-ft). It gets the

Discovery to 100 km/h in 8.3 s, the engineers claim. Common rail injection pressure is 2200 bar. The range also includes a 3.0-L V6 gasoline with 250 kW (348 hp) output and 450 N·m (332 lb-ft). All engines get an 8-speed ZF automatic transmission. A 2-speed transfer case is standard.

New 'Nose Load Measurement'

Chassis systems are extensive and include All-Terrain Progress system (allowing the driver to set crawl speeds from 2 km/h to 30 km/h), controlling engine and braking. It also gets Terrain Response 2,

automatically monitoring driving conditions that span regular driving to rock crawl via gravel, sand and mud modes.

Maximum towing capacity is 3500 kg (7716 lb) and Advanced Tow assist is available. A semi-autonomous system for reversing, the driver uses a rotary switch on the central console after configuring requirements on the car's central screen. Responsive trajectory lines help the driver, with information fed from cameras fitted to the car's door mirrors.

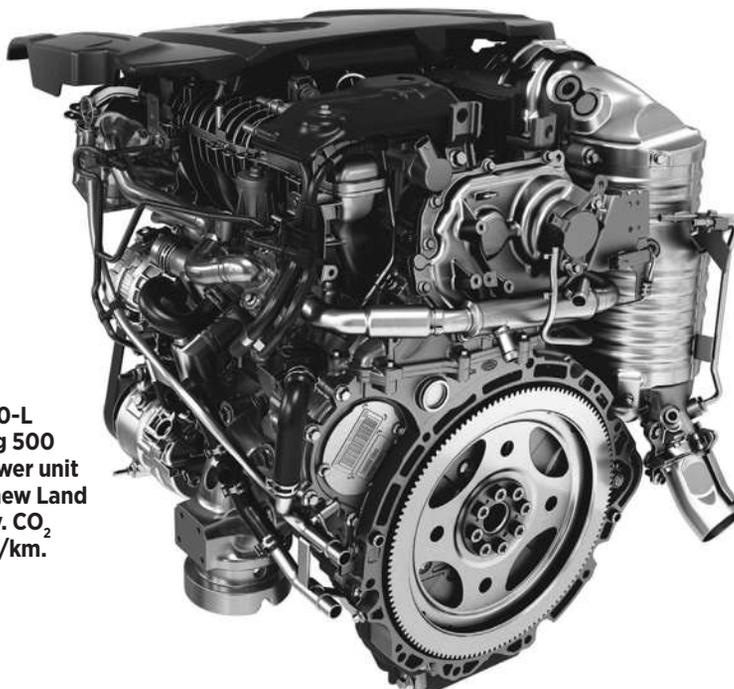
A claimed "industry-first" is Nose Load Measurement that facilitates a quick check on weight being applied to the towbar by a trailer to ensure it is within a 129-kg (284-lb) limit. It can be operated via the Discovery's touch-screen or a smartphone.

Interior packaging improvements

Vehicle length is 4970 mm (196 in) on a wheelbase of 2922 mm (115 in). Height is 1846 mm (72.6 in) and width including mirrors 2220 mm (87.4 in).

Packaging has been a major aspect of all Discovery iterations. The Discovery has a one-piece upward opening tailgate but there is also a powered, fold-down panel that doubles as a load restraint and also as a 285-mm-long (11.2-in) bench for event seating such as horse shows. It is designed to support a weight of 300 kg (661 lb), to cope with the Discovery's occupants consuming an exceptionally good picnic lunch.

Stuart Birch



Four cylinder 2.0-L diesel delivering 500 N·m is in the power unit line-up for the new Land Rover Discovery. CO₂ emissions, 171 g/km.

Global VEHICLES

With 2017 Fusion Sport, Ford pushes further toward Audi



The 2017 Fusion Sport marks several “firsts” for Ford and the midsize-sedan segment.

Nobody’s ever had much trouble liking the sleek look and agreeable driving dynamics of Ford’s Fusion midsize sedan since the second-generation model was launched for the 2013 model year. But three years into its lifespan, a refresh is due—and in addition to a not-so-you’d-notice front-styling revision and some unexpectedly high-quality interior upgrades, the 2017 Fusion lineup adds a convincingly-executed Sport model to slant this family car distinctly to the sport-sedan part of the spectrum.

Todd Soderquist, global chief program engineer for the Fusion and Mondeo, told *Automotive Engineering* that because Ford’s new-ish twin-turbocharged 2.7-L V6 was developed concurrently with the second-generation Fusion, the midsize sedan was designed from the start to accept the EcoBoost V6, even though the car was launched with a 4-cylinder-only engine lineup. Thus the heart of the new Fusion Sport, the 2.7-liter—here generating an SAE-certified 325 hp (242 kW) and a chesty 380 lb-ft (515 N·m)—was three years ago ready for this duty.

At last, a V6 for the Fusion

The EcoBoost V6 represents a blustery 80-hp (107-kW) and 105 lb-ft (142 N·m) boost over the Fusion’s next most-powerful engine, the turbocharged 2.0-L 4-cylinder. The power upgrade is significant, but curiously in this era of engine downsizing, part of the Fusion Sport’s reason for being is old-school cylinder count: Ford reckoned the Fusion was losing out to at least two of its chief competitors, the Toyota Camry and Honda Accord, which still (almost inexplicably, we think) offer V6 power.

There’s another, bigger-picture reason it’s a good time for the Fusion lineup to get a shot in the arm: midsize family sedans, the time-honored cornerstone of the passenger-vehicle market, are fast losing ground to crossover vehicles. In August this year, sales of midsize sedans hit a five-year low, according to trade journal *Automotive News*.

This 2.7-L is somewhat special in the already tech-rich feature set of all EcoBoost engines in that it features Ford’s first use of a compacted-graphite iron (CGI) cylinder block for a gasoline engine (see <http://articles.sae.org/13388/> for more



All Fusion models get a quite mild exterior refreshing for 2017; one visual giveaway for the Fusion Sport is quad exhaust tips.

detail). Manufactured in Lima, OH, the engine’s CGI construction blends the durability attributes of grey iron with weight-savings similar to (or potentially better than) aluminum. Already used for the F-150 pickup and the Edge Sport crossover, for the Fusion Sport the V6’s torque peak is slightly higher even than the F-150 pickup’s rating. There also are several SAE technical papers relating to the EcoBoost 2.7-L; one starting place is <http://papers.sae.org/2015-01-2288>.

The addition of the grunty V6 unquestionably adds a new dimension to the Fusion, delivering brash acceleration from a standstill, even if the collaboration between the V6 and an uprated version of Ford’s 6-speed automatic transmission doesn’t seem entirely copacetic. *Car and Driver’s* experienced speculation indicates the Fusion Sport will cut about a 5.3-s 0-to-60 mph run, a figure that requires no excuses in sport-sedan company. Thanks to a “sport” button centered in the new rotary-dial shifter, the engine-transmission interface can be made more urgent and the engine’s aural output is enhanced to a slightly too-loud and almost uncomfortably artificial howl.

Pin the throttle in a tight backroad bend and the V6 has the Fusion Sport bolting with authority—just when you’re sure that



blistering torque will send a front wheel fluttering, the standard all-wheel drive swallows the excess and channels it where it won't be wasted. This combo alone makes the Fusion Sport well worth its \$34,350 starting price, even if with all this thrust hardware it still seems the car should be able to do better than its mediocre 21-mpg combined fuel-economy rating. In this metric, the Fusion Sport's plumpish 3982-lb (1806-kg) curb weight—450 lb-plus (204-kg) more than a front-drive, 4-cylinder Fusion—surely is no advantage.

First adaptive damping for family sedan

What may be as impressive as the Fusion Sport's propulsion-per-dollar ratio is its continuously controlled damping (CCD) suspension—the adaptive dampers the company uses in several Lincoln models, the system's first-ever standard-equipment appearance in a U.S.-market Ford-branded vehicle.

The CCD dampers, made by **Tokico** but algorithmed by Ford specifically for the Fusion Sport, receive input from a dozen high-resolution sensors and are said to react in 30-50 ms to adjust damping rates. The Fusion Sport is the first car in its class to offer electronically-controlled adaptive damping and it's an upgrade we predict competitors—particularly those with sporting pretensions—are likely to adopt: CCD's impact on the Fusion Sport is stupendous.

The system slurps up the most distressing road-surfaces with disdain; hard-driving on twisting and poorly maintained backroads, the kind of challenge that can leave even sport-oriented vehicles wallowing for grip and suspension fluidity, is handled brilliantly by CCD. We can't think of many Germany sport sedans that have better body control or could feel any more pinned to the road than the Fusion Sport. It's a highwater mark for the Fusion's already solid CD4 platform.

The secondary joy of CCD is that the system doesn't seem to require selecting the car's "sport" driving mode—sharper steering, throttle and transmission response and overall stiffer damping calibration—to get most of the benefits. We



2017 Fusion models are treated to a host of interior revisions and additional electronic features; Sport gets specific seats and instrument-cluster configurations.



Signature new feature of the 2017 Fusion interior remake is rotary-dial gear selector; sport mode has easily accessed central pushbutton.

found the base tuning's automatic responses adequate to handle fairly aggressive cornering while still delivering superb comfort. Ride quality, in fact, seems little compromised even when sport mode is selected.

The Fusion Sport's chassis upgrades also run to stiffer rollbar and spring rates. There are special 19-in alloy wheels and the front brake rotors are larger (by some unspecified amount) than the 11.8-in front discs of the standard Fusion. The increase or its related calibration isn't enough, as probably the Fusion Sport's only chassis shortcoming is limp braking.

Better vision for better interior

Like CCD, you can't help but notice the Fusion Sport's signature interior feature, a change from a center-console shift lever to a rotary dial. It's also on the center console but offset to the driver. The dial does palpably open the center-console area, and the standard shift paddles handle the transmission-control functionality lost with the shift lever.

Less apparent than the new shifter is an upgrade of certain interior trim pieces—including a surprisingly rich, soft-touch upper covering the bulk of the upper dash—and slimmed A-pillars that noticeably improve sightlines. And the new "Miko" microsuede (think Alcantara by a different name) mixes with leather for the seats to lend a sporty and premium appearance, as well as some degree of grip during spirited driving. All 2017 Fusions benefit from the rotary shifter, improved interior trim and slimmer A-pillars.

Several available electronic-feature upgrades for all 2017 Fusions include adaptive cruise control with collision-avoidance braking and genuine stop-n-go functionality in traffic, lane-departure warning and lane-keeping assist, as well as automatic parking capability that adds auto-parking for standard parking spots in addition to parallel parking.

The new Sync 3 driver-interface system is optional and incorporates **Apple** CarPlay and Android Auto integration.

Bill Visnic

Citroën unveils CXperience concept at 2016 Paris show



Citroën's CXperience concept has a 3-m wheelbase and is only 1.37-m tall. The concept vehicle debuted at the 2016 Paris Auto Show.

Having shrugged off the inhibiting effects of conventional design that took it into the category of the mundane for many years, PSA Citroën's latest demonstration of its original technological and aesthetic design capabilities for its Citroën brand is the CXperience concept, unveiling at this fall's 2016 Paris Auto Show.

A gasoline plug-in hybrid with a maximum combined power output of around 220 kW (295 hp), it has progressive hydraulic "cushion" suspension (<http://articles.sae.org/14867/>) and a long (4.85-m / 15.7-ft) and low (1.37-m / 4.5-ft-high) body. The concept sits on 22-in wheels and features aft-hinged rear doors. The overall exterior form has a bit of the radically different 1955 DS about it, including a single-spoke steering wheel.

CXperience marks a new offensive in brand strategy, according to Citroën CEO Linda Jackson. Interviewed by the author late last year, Jackson indicated that the company would re-establish its focus on comfort and individual design.

Said she of the new concept: "It challenges convention. It also fits in perfectly with the ambitions of the Citroën Advanced Comfort Program and illustrates our 'be different, feel good' promise in this segment."

That segment is described as an executive (luxury) hatchback. The concept has highly distinctive frontal treatment that includes V-shaped LED daylight running lights (DRL) comprising narrow strips above three LED directional headlights. Active air intakes integrated into the bumpers improve aerodynamic and thermal efficiency.

The rear window is concave with what Citroën describes as a "moving fin" aerodynamic aid. Laser fiber optic rear lights are fitted. And the backward-opening closures are described as "autoclave doors." The car has twin sunroofs.

Exterior mirrors are replaced by rear-view cameras; images are sent to small screens positioned along the inner door panels, which also carry speakers and air vents.

Exterior rearview cameras take the place of conventional side mirrors on the Citroën CXperience concept. Can this technology for production vehicles be far behind?



The car's dashboard comprises a 19-in rectangular touch-screen that can be configured in one, two or three sections. It is central to an interior that makes unusual use of fabrics, including textured leather floor covering bordered by chrome-finish sills. Shape-memory foam is used for the seats.

Occupant information sees emphasis placed on a very wide range of connected services. Those sitting in the back seats have a mobile tablet giving access to seat adjustment and air conditioning, plus media sharing via a new app: Share with U.

A head-up display (HUD) is fitted. Placed behind the interior rear view mirror is a wide angle HD camera capturing the view ahead. Images can be stored or shared on social networks.

The CXperience can be used in zero-emissions mode with a range of up to 60 km (37 m), its lithium-ion battery re-chargeable in a claimed 4.5 h with a standard domestic charging system, but "less than" 2.5 h using a solution based on a specific hybrid vehicle charger. The battery is tucked away under the car's floor and drives the rear axle.

An 8-speed electrically-actuated automatic gearbox is positioned between the gasoline engine and the electric motor which can deliver up to 80 kW (107 hp).

Stuart Birch



Citroën CXperience concept: Rear-hinged back doors are often a favorite for concept cars but few make it to production.

Volvo S90: Niche for now, but...



The 2017 Volvo S90 leverages all of Volvo's most recent major vehicle-development investments: an all-new platform and engine family and its latest autonomous-driving innovations.

It's no secret the reconstituted **Volvo**, since 2010 owned by China's **Zhejiang Geely**, is doing interesting and innovative things—one of the most intriguing, maybe, being that it's survived and in some senses thrived (particularly if fellow Swedish auto brand Saab is used as a measure) under Geely's control.

Fact is that Volvo and Geely have shut up the naysayers: in the nearly seven years Geely's been in charge, a studied and benevolent guidance (not to mention \$11 billion in product-development funding announced in 2012) has delivered a Volvo that's somehow managed to evolve its brand back to a relevancy few thought it could ever recover.

Geely and Volvo well know the auto business maxim that "product is king" and after a transition period that left showrooms thin with transition product, the new-generation Volvo is emerging. First (and perfectly timed for a crossover-crazy U.S. and Europe) was the XC90 fullsize crossover (<http://articles.sae.org/13390/>) built on the company's new, widely-adaptable Scalable Product Architecture (SPA) platform.

Now the S90 sedan—also based on SPA—is ready and the dwindling interest in sedans in every market segment will only add pressure on Volvo's latest attempt to tackle the German luxury-brand triad to which every luxu-sedan is compared.

"Not a sport sedan"

Volvo wisely is trying to play off its reinvented brand—a niche image the "former" Volvo could never fully accept—saying matter-of-factly at a recent media launch that the 2017 S90 "is not a sport sedan." With that off the table, the S90

can go about being what it is: a roomy, comfortable and safety-focused luxury car that's more about safety and minimizing environmental impact than carving backroads.

Beyond the apparently wide size flexibility that its SPA architecture imparts, the S90's Drive-E engines perhaps are its



Part of owner Geely's massive investment in Volvo is a range of high-tech modular 4-cylinder "Drive-E" engines. This range-topping variant uses supercharging and turbocharging to mitigate turbo lag.

Global VEHICLES

most fundamentally impactful engineering. For the U.S., the gasoline 4-cylinder 2.0-L Drive-E engine comes in two configurations: a turbocharged variant for front-drive S90 T5 models that develops 250 hp and 258 lb-ft (350 N·m). The all-wheel-drive S90 T6 is fitted with a turbocharged and supercharged version of the same 2.0-L that cranks up output to 316 hp and 395 lb-ft (536 N·m). Next year, Volvo will offer the wonderfully complex plug-in hybrid variant of this setup for the S90.

At 195.4 in, the S90 is marginally longer in overall length than the **BMW 5-Series** and **Mercedes-Benz E-Class** and is almost exactly the same length as **Cadillac's CTS**, but the Volvo weighs at least a couple hundred pounds more than any of the three, so the energy with which the T6 engine propels the S90 is practically a dynamic revelation. This and the Drive-E engine's smoothness and isolation from the passenger compartment means any concern about cylinder count and refinement effectively is not a concern. The supercharged/turbocharged 4-cylinder is, as claimed, all but free of perceived turbocharger lag and the AWD system ensures that no uncouth torque steer reveals to the driver that there's a hard-working 4-cylinder up front.

The standard 8-speed automatic is an agreeable collaborator and helps this mighty engine to settle in enough to deliver a 34-mpg highway rating and 27 mpg combined.

Refinement and technology focus

The T6s *Mobility Engineering* drove also displayed rewarding ride quality—particularly those cars with the optional air suspension to augment the car's distinctive independent rear-axle design that employs a single transverse leaf spring that collaborates with the hydraulic or air dampers. The front suspension for all S90 models is a double-wishbone layout that delivers the fine steering precision expected of this typically more-expensive design.

So the 2017 Volvo S90 is large enough inside to telegraph true luxury—even if, frankly, some of the interior trim and equipment don't totally seal the deal—and offers enough performance to back up the luxury claim. So Volvo



The S90 interior follows the inevitable trend towards larger touchscreen driver interface. The S90 touchscreen has brilliant resolution and integration into the dash, but its operational logic can be perplexing.



With roughly the exterior size of the **BMW 5-Series** or **Cadillac CTS**, the S90 cabin is spacious and comfortable, although the “depth” of some luxury details isn't up to the standards of costlier competitors.

thinks its competitive edge—apart from openly not trying to compete on “sporting” credentials—will be in its envelope-pushing use of autonomous technology.

The S90, Volvo claims, is the first car in the world to offer a standard-equipment semi-autonomous driving system (<http://articles.sae.org/14568/>)—Pilot Assist II—a “hands-on” configuration

that steers and brakes on highways and at speed up to 80 mph. Volvo is careful to say Pilot Assist is mainly designed to reduce the fatigue of driving in stop-and-go traffic. The system is bolstered by the S90's “road-edge detection,” which Volvo similarly said is the world's first system to eliminate accidents caused by running off the road.

Bill Visnic

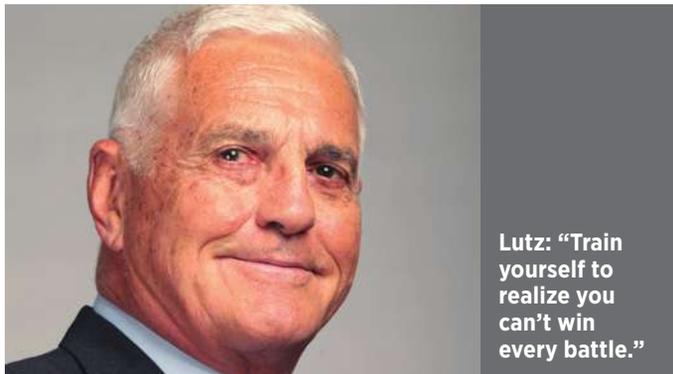
COMPANIES MENTIONED

3M.....	44	Dassault Aviation.....	13	John Deere.....	11, 46, 48	Shell.....	8
Acura.....	41	Dassault Reliance Aerospace.....	13	Kanagawa Institute of Technology.....	23	Shell Oil.....	21
Aderis Technologies.....	44	Dassault Systems.....	8	Knowledge Institute of Technology.....	11	Siemens.....	8
Adomani.....	33	DDIPL.....	10	Lamborghini.....	17	Siemens PLM Software.....	9
Airbiquity.....	32	Defense Automotive Technologies Consortium.....	4	Land Rover.....	28	Simpson & Co.....	10
AK Steel.....	43	DowAksa.....	43	LG Chem Power.....	29, 30	S.M.A. Metaltechnik.....	35
Alcoa.....	44	Dralon.....	44	Lightweight Forging Initiative.....	45	Society of Indian Automobile Manufacturers.....	9
Alphabet.....	29	Dresden University of Technology.....	35	Lincoln.....	44	Stanley Engineered Fastening.....	35
Altair.....	8	Ducker Worldwide.....	36, 44	Mahindra & Mahindra.....	6, 9, 14	Strategy Analytics.....	32
American Lightweight Materials Manufacturing Innovation Institute.....	45	Eaton.....	11, 21, 33	Maruti Suzuki India.....	8	TAFE.....	9
American Motors.....	64	Eleation.....	8	Mazda.....	19, 23, 41	TARDEC.....	4
Ansys.....	8	Emhart Teknologies.....	35	MEKRA Lang.....	35	TCS.....	6
Apple.....	59	FEV.....	46, 49	Mercedes-Benz.....	62	Tenneco.....	24
Argus Cyber Security.....	32	FISITA.....	6	Mississippi State University.....	21	Tesla.....	32, 35, 42
Ashland.....	44	Ford Motor Company.....	35, 38, 43, 58	Monroe.....	24	Tokico.....	59
Atlas Copco.....	44	FPT.....	47	Movimento.....	32	Total.....	8
Audi.....	17, 35	Fritzmeier Systems.....	34	MRF.....	8	Toyota.....	58
Automotive Research Association of India.....	10, 11	GE Aviation.....	6	MSIL.....	9	Tripti Hospitality.....	8
AVL.....	8, 47	General Motors.....	19, 38, 42, 64	NanoSteel.....	43	Tube Investments of India.....	9
Bentleys.....	17	Gestamp North America.....	42	NASSCOM.....	6	Unigraphics.....	8
Bimetal Bearings and IP Rings.....	9	GKN.....	8	NHTSA.....	4, 33, 46	University of Tsukuba.....	23
BMW.....	35, 44, 62, 64	Google.....	29	Nissan.....	15, 41	UQM Technologies.....	33
Boeing.....	51	Grammer.....	35	Novelis.....	43	U.S. Army.....	4
Bosch.....	13, 27, 34	Grede.....	45	Oak Ridge National Laboratory.....	19, 44	U.S. Department of Energy.....	19, 21, 29, 43
BP Castrol.....	20	Hella.....	34	Paccar.....	21	U.S. Department of Transportation.....	4
BPCL.....	8	Henkel.....	44	Peugeot Citroën.....	26	U.S. Environmental Protection Agency.....	19, 33, 46
Cadillac.....	44, 62	Hindustan University.....	8	Pi Inno.....	33	U.S. Marine Corps.....	64
CAR.....	19	Hitachi Automotive.....	23	Pinnacle Industries.....	13	VDL Groep.....	13
Castrol.....	8	Honda.....	19, 44, 58	Porsche.....	17	VDL Pinnacle Engineering India.....	13
CATIA.....	8	Honeywell.....	6	PPG.....	44	VDL Steelweld.....	14
CEAT.....	8	Horiba.....	8	PSA Citroën.....	60	Viper Hobbies.....	8
Center for Automotive Research.....	41	Hybrid Kinetic Group.....	33	PSNACET.....	12	Volvo.....	61
Chevrolet.....	41	Hyundai.....	38	Rajagiri College of Engineering & Technology.....	10	VW Group.....	17
Chitkara University.....	6	Indian Oil.....	6	Range Rover.....	25, 56	Wuzhoulong Motors.....	33
Chrysler.....	44, 64	IHS Automotive.....	41	Reliance Group.....	13	Yangtse.....	33
Citroën.....	26, 60	Infiniti.....	15	Renault.....	64	ZF.....	17
CNH Industrial.....	47	Institute for Advanced Composites Manufacturing Innovation.....	44	Renault Nissan.....	9	Zhejiang Geely.....	61
COMSOL.....	30	Insurance Institute of Highway Safety.....	43	RMX Technologies.....	44		
Continental.....	8	ITL.....	33	RSET.....	10		
Corning.....	43	Iveco.....	47	SAE International.....	4, 6, 17, 19, 20, 30, 34, 46, 58		
Cummins.....	32	JaguarLandRover.....	27, 35, 56	Safran.....	6		
Cummins Technologies India.....	10			SGL Group.....	44		

AD INDEX

Altair Engineering Pvt Ltd.....	5	altairhyperworks.in/hw14
.....		www.altair-india.in
AR RF/Microwave Instrumentation contact for India.....	Cover 3	www.arworld.us
.....		www.complus.in
Borg Warner.....	7	borgwarner.com
COMSOL Inc.....	Cover 4	comsol.co.in/application-builder
Molex Incorporated.....	Cover 2	www.molex.com/a/powertrain/in
Smalley.....	3	smalley.com/samples
.....		smalley.com/retaining-rings

Q&A



Bob Lutz: What makes a great engineer?

Throughout the 2016 documentary film *Live Another Day* about the fall and rise of the Detroit-3 automakers, former GM Vice Chairman Bob Lutz shows the insight and enthusiasm that made him one of the industry's most effective "product guys" for four decades. While Lutz, now 84, actually holds a marketing MBA, his practical knowledge of aircraft design, systems and aerodynamics learned as a **U.S. Marine Corps** fighter pilot combined with a life-long love of cars, motorcycles and aircraft made him, as he says, "a close friend of engineers and designers." He spoke recently with editor-in-chief Lindsay Brooke.

I've met many good engineers in my 30-plus years covering the industry. But what makes a great one?

Truly great engineers obviously have the intellect for handling the complexities of the math, combined with a thorough passion for the product. They tend to be left-and-right-brained thinkers. The president of a major engineering university once told me that General Motors would only recruit his students who had the top grade-point averages. He argued that grade-point average alone does not make the best engineers. He said the kids he'd hire himself are the ones who might have a 2.7 [GPA] but who are absolute fanatics about whatever project they're working on. They've got dirty fingernails from testing their theories and some even cut short their study time because they're so passionate about their projects.

I agree. Some of the best engineers I've worked with are hands-on, very outcome-focused. And non-political.

What about leadership?

The passionate engineer then must trigger that same or greater enthusiasm in the people he or she is leading. Two people come to mind whom I think were exceptionally good at that. First and foremost is Francois Castaing [Executive VP of Engineering at Chrysler during its 1990s heyday who achieved earlier successes

at **Renault** and **American Motors**]. Castaing was fabulous—he'd been in charge of Renault's Formula 1 racing team. In racing if you don't win on Sunday you re-design on Monday, you finish re-engineering the new parts on Tuesday and Wednesday, you fabricate them on Thursday and you test on Friday. It's all short lead time, roll-up-your-sleeves and get the job done.

Francois was like that—and constantly doing things that were accepted by the system as being impossible. He loved challenges.

The other great engineer is Jim Queen [former GM Group VP Global Engineering], a superb leader and former Marine pilot who flew F4 Phantoms. I felt that Jim got a lot of things done by the power of his leadership that lesser people couldn't have accomplished. Jim wasn't as enthusiastic about driving as Francois was—at the proving ground I never got to drive first if Francois was there.

How is it that engineers who are highly effective simply being engineers often turn out to be much less so when they move into management?

Even Francois found that to be tough, because he couldn't understand senior management decisions that were counter-intuitive. But you just train yourself to realize you can't win every battle.

What's the key to engineering greatness?

The willingness to take intelligent risks—both reputational and risks with the product. If you're not willing to put your credibility on the line, I don't think you're going to achieve anything. To always 'go with the flow' is not great-engineer stuff.

How about great engineers at BMW?

When I was at **BMW** [1971-74, Executive VP Global Sales and Marketing] there were almost no engineers in senior positions. There were plenty of bureaucrats, however. That was my big surprise when I first went to BMW from GM Europe. I thought everybody was going to be enormously product focused, like me, and passionate about the cars.

When I wanted to put some nice artwork of BMW's racing history in the lobby of the top floor of BMW headquarters in Munich where the chairman and members of the management board had their offices, I was told, 'Mr. Lutz, the senior executive floor is a dignified place. Automotive subjects have no place here.' That surprised the hell out of me and it made me wonder how we made such great cars. Then I found out senior management was blissfully unaware of what was going on in the product area.

At BMW the great engineering took place at a level well below senior management. We had Alexander von Falkenhausen, the brilliant engine guy. He did our first V-12 based on two 2.5-L inline sixes, in a few weeks.

The truly great engineers like Castaing, Queen and von Falkenhausen tend to be outcome-oriented versus process-oriented. That counts a lot with me because that old 'if you get the process right, the product will be right' bullshit often doesn't work. If you have a perfect process with the wrong goals, you won't have anything worthwhile.

Lindsay Brooke

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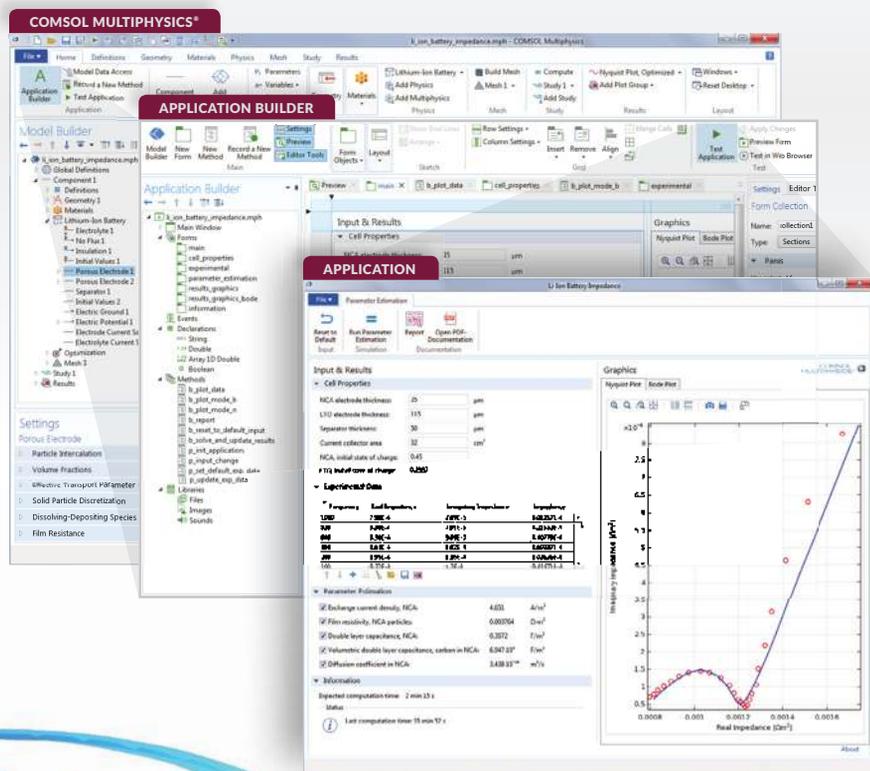
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