

MOBILITY ENGINEERING

AUTOMOTIVE, AEROSPACE, OFF-HIGHWAY

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

Vistara soars toward expansion

New flight-planning technology
enhances safety, cuts costs



Base-engine value engineering

Deriving optimum efficiency, performance

Autos & The Internet of Things

How the IoT is disrupting the auto industry

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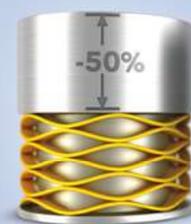
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Bill Visnic
Editorial Director
bvisnic@sae.org

Asit K. Barma
SAEINDIA Editor

C. V. Raman
ED, MSIL
CV.Raman@maruti.co.in

Arun Jaura
VP, SAEINDIA
arunjaura@gmail.com

Bala Bharadvaj
MD, Boeing R & T
bala.k.bharadvaj@boeing.com

Mathew Abraham
Sr. GM, Mahindra
ABRAHAM.MATHEW@mahindra.com

Dr. Venkat Srinivas
Vice President & Head -
Engineering & Product
Development, Mahindra &
Mahindra Truck and Bus Division
srinivas.venkat@mahindra.com

Lindsay Brooke
Editor-in-Chief
abrooke@sae.org

Ryan Gehm
Associate Editor
rgehm@sae.org

Patrick Ponticel
Membership Editor
ponticel@sae.org

Lisa Arrigo
Custom Electronic
Products Editor
larrigo@sae.org

Contributors

Kami Buchholz
Detroit Editor

Stuart Birch
European Editor

Jack Yamaguchi
Asia Editor

Steven Ashley
Dan Carney
Terry Costlow
Richard Gardner
John Kendall
Bruce Morey
Jennifer Shuttleworth
Linda Trego
Paul Weissler

DESIGN

Lois Erlacher
Creative Director

Ray Carlson
Associate Art Director

SALES & MARKETING

G. Vijayan
SAEINDIA
No.1/17, Ceebros Arcade
3rd Cross Kasturba Nagar
Chennai
India 600 020
(T)91-44-42152280
(E) ddg@saeindia.org

Marcie L. Hineman
Global Field Sales Manager
+1.724.772.4074
hineman@sae.org

Electrification no longer the auto industry's 'moonshot'

I never feel intellectually prepared to absorb the cascade of information and ideas from the SAE World Congress. This April's Congress was no exception, but I was able to wrap my mind around at least one palpable theme: electrification is set to engulf vehicle design and development more quickly and pervasively than we would have even a few years ago imagined.

It wasn't only because of my perception that so many technical papers, expert panels and other discourses at the World Congress centered on electrification. It's because electrification now seems to dominate the daily news from every corner of the auto industry.

I was astonished in late March, just weeks before the World Congress kicked off, when news came that India's government is contemplating a plan to have nothing but battery-electric cars on the country's roads by 2030. Could electrification of India's entire light-vehicle population be the country's contemporary version of President Kennedy's 1961 promise that the United States would have a man walk on the moon by the end of that decade?



Mahindra e20 electric vehicle: the beginning of the revolution?

India is giving itself a little more time than the eight or nine years the U.S. had when Kennedy set perhaps the nation's most famous stretch goal. But if one considers the almost inconceivable pace of electronics development, it seems that in 2016, India's ambition has better odds of happening than did a moon landing by the end of the 1960s.

The drive to electrification suddenly seems inexorable, and because of that, almost no promise or prediction about its adoption can be dismissed as too outrageous—or too optimistic. India has about 13 years to attain its

goal. When the first **Tesla** Roadster was sold in 2006, could anyone have imagined that just 10 years later, Tesla would be brazenly filling its order books for a \$130,00 battery-electric luxury crossover vehicle, the Model X, or would be able to unveil the high-volume, relatively affordable Tesla Model 3 (see pg. 56)?

Or what about **Volkswagen's** plan to have 20 different plug-in vehicles available in little more than three years' time? One of the most intriguing aspects of the company's diesel-emissions calamity is VW Group CEO Matthias Muller's vow to "make electric cars one of Volkswagen's new hallmarks." If a company of VW's scale was to go "all in" on electrification, would that not be considerable accelerant in the brewing chemistry of electric-vehicle development?

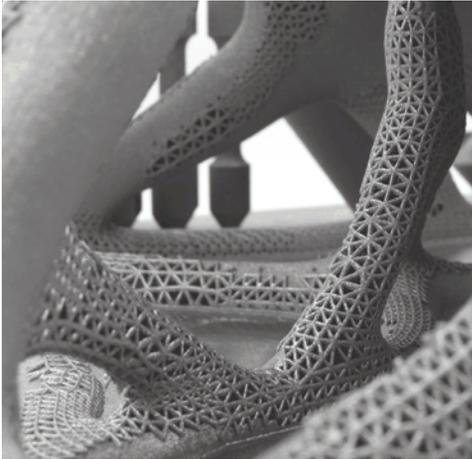
Almost hand-in-hand with VW's declared intention was Germany's adoption of a \$1.4-billion incentive program to spur electric-vehicle development and adoption. The program includes handsome incentives for German consumers (as, reportedly, does India's nascent electrification plan) and the installation of some 15,000 charging stations across the country so famous for its embrace of combustion-propelled high velocities.

There are other angles to consider as well, as Keno Kato, **Nissan's** Corporate Vice President, Global Product Strategy & Product Planning, told me at the New York auto show earlier this year. You can read some of his fascinating comments on page 64, but Kato insists global warming is the most pressing issue for the auto industry—and, by extension, the world. Electrification of ground vehicles is, of course, viewed as a prime method to reduce greenhouse-gas emissions.

Back to the World Congress. The discussion panels and technical sessions brimmed with talk not necessarily of a country using nothing but electric cars—but the now increasingly clear and attainable development steps to getting there. Electrically driven turbochargers, 48-volt electrical architectures and increasingly more-electrified hybrids all are here and now. And the speed with which today's electronic innovations are being supplanted means I wouldn't bet against India's electric-car moonshot.

Bill Visnic
Editorial Director

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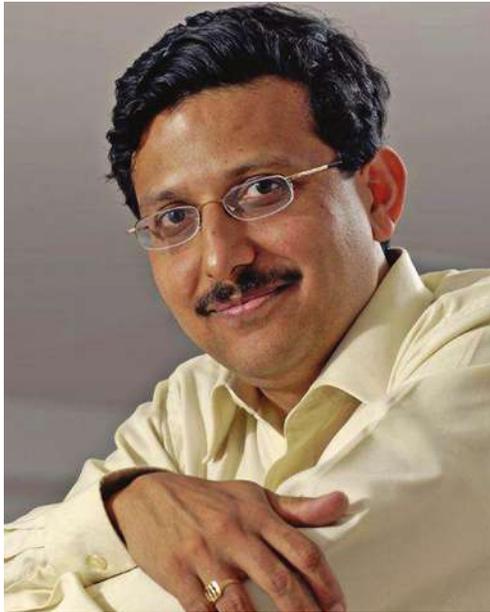
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FOCUS

SAEINDIA begins 2016 with pulsating energy, optimism

I couldn't have hoped for a better first quarter of 2016: we were able to pack many programs and events under all verticals, in addition to our flagship programs, BAJA SAEINDIA and AWIM National Olympics—both of those events setting new milestones and scaling greater heights.

The SAE Board of Directors assumed charge in January and Dr. Bala Bharadvaj and I were invited to make a presentation during the SAE board meeting that, incidentally, was held in India for the first time. There was widespread praise and appreciation from the



Dr. Aravind Bharadwaj
President, SAEINDIA

SAE directors who participated in the events organized by SAEINDIA in Pune, Bangalore, and Chennai, and they were impressed with the excellent work in which SAEINDIA is engaged throughout the country.

A networking dinner in January truly was a spectacular event, with plenty of camaraderie and bonhomie from years of association. The industry invitees embellished the evening with a platform for networking with the SAE International Board of Directors and elders who had done pioneering work during the formative years of SAEINDIA.

The SAE International team also participated in the National Olympics of AWIM in January at Mahindra Research Valley, Chennai, which was another grand success, as hundreds of children competed, joyfully displaying their ingenuity and imagination. India's winning team traveled to Detroit in April to participate in the International Olympics during

the SAE World Congress. The successive AWIM Organizing Committees seem to set the bar higher with each year's event.

SIIMC 2016 was organized at the India Habitat Centre in Delhi and coincided with Auto Expo. The technical-paper presentations and technical sessions set a new benchmark in terms of quality and the variety of topics addressed. Keynote speeches and the panel discussion brought together experts from diverse disciplines in the automotive industry; the event included renowned leaders from abroad, making the conference an intellectually gripping event.

In February, the ninth edition of BAJA SAEINDIA was organized at Pithampur, Indore. As seems typical for this grueling competition, the teams appeared to face insurmountable tasks—yet completed the course with guts and gusto. The enthusiasm of the BAJA contestants has to be seen to be believed. This competition has become one of the most-coveted events for engineering students all over India and I look forward to this event scaling up in the near future to include teams from Southeast Asia countries.

SAEINDIA marked its 20th Anniversary in March with a celebration in Chennai with a gala function that included Mr. R. Seshasayee, Chairman of Infosys and Executive Vice Chairman of Hinduja Group as the chief guest. He paid a handsome tribute to Dr. Pawan Goenka for being chosen by FISITA for the Medal of Honor Award, to be presented during the FISITA World Automotive Congress in Busan, Korea. Dr. Goenka recalled for the audience when he was appointed an advisor to establish SAEINDIA in 1995 to help define for the organization a role for the Society to play in the future needs of industry and the mobility community.

At the anniversary gathering, a splendid coffee-table book was released by the chief guest. The book portrayed SAEINDIA's journey over 20 years with photographs and contributions from many of the doyens and leaders of SAEINDIA. It also was truly gratifying to have two donors, ANSYS and Turbo Energy Ltd. contributing generously to the AWIM Corpus Fund during this event. I'm sure that this corpus will swell with future contributions from other organizations. The corpus was created to finance the annual outlay of the AWIM and help this event to reach out to more of India's students.

The first quarter of 2016 pulsated with action-packed programs and events, hoisting the flag of SAEINDIA higher in the national and international arena and providing us all with tremendous satisfaction and personal fulfillment.

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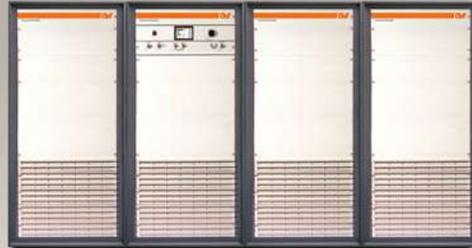
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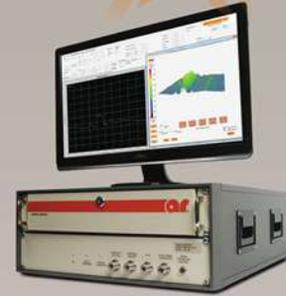


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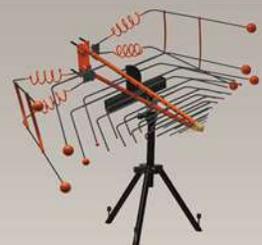
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SAEINDIA off-highway leadership enclave held in Pune

The Society of Automotive Engineers (SAEINDIA) Off-Highway Board, in association with Automotive Research Association of India, **Ansys, Cummins India, Eaton Technologies, JCB, John Deere** and **PTC** in January organized a Leadership Enclave themed, "Off-Highway Industry – Growth Through Leveraging Talent and Technology Innovations" in Pune.

The event was attended by Cuneyt Oge, 2016 SAE International President; Chris Myers, Director, Deere and Company; Tom Stover, VP Commercial Vehicle, Eaton Corp; and Murli Iyer, Executive Advisor - Global Affairs, SAE International. Also attending were leaders from Cummins, **Automotive Research Association of India (ARAI)**, Ansys, Cummins India, Eaton Technologies, JCB, John Deere and PTC and SAE board members.

There was a panel discussion during the event with: Amit Agarwal, Regional Director - Support and Services, Ansys; Devendra Bahirat, Business Head, John Deere Electronics Solutions; Paul Sowerby, CTO, Cummins India; and Dr.



Inauguration by SAE International President and distinguished SAE International members on Jan. 19.

K.C. Vora, Sr. Dy. Director, ARAI. The discussion topic was "Innovation and Talent in the Off-Highway Industry."

The panel discussion included several topics:

- The kind of revolution foreseen in the off-highway industry and how to make it happen.
- How can innovation in the off-highway industry help meet the challenge of

implementing BS VI by 2020?

- Methods to improve the success rate of idea generation to commercialization.
- How the current pool of young talent can be the growth accelerator in the future for the off-highway industry to fulfill the demands of competitive economies.
- How to improve skill development in off-highway industry with respect to all disciplines.

Eighth AWIM National Olympics held in Chennai



The eighth AWIM National Olympics was conducted at Mahindra Research Valley, located at Mahindra World City near Chennai on January 22 and 23, 2016. A state-of-the-art auditorium was used for briefing participants and group meetings, while the competition tracks were placed in the venue's spacious halls and a comfortable reception area was used for toy-making participants.

The National Olympics turned out to be a grand success, with participation from 47 Teams representing 19 cities across India. Of the total, 37 teams of sixth-graders took part

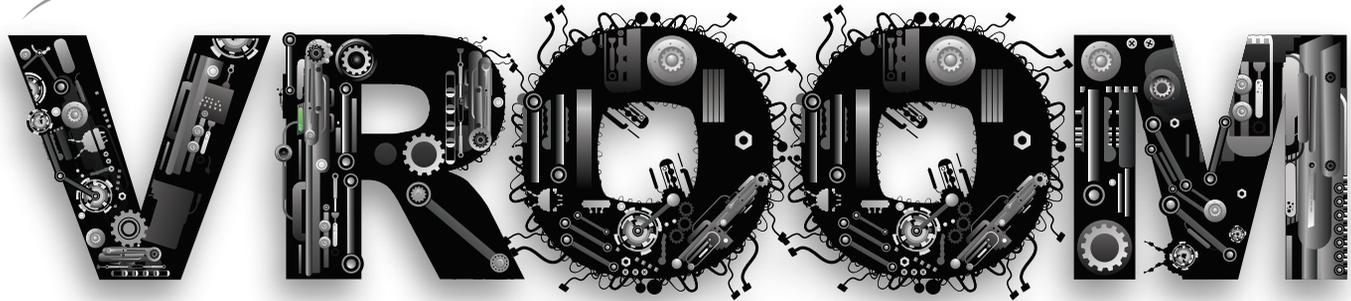
in Jet-Toy challenge and 10 teams of fifth-graders competed in the Skimmer challenge.

SAEINDIA, in association with primary sponsor **Mahindra and Mahindra** and co-sponsor **Eaton India** joined associate sponsors **Turbo Energy (TEL), ANSYS, Continental Automotive Components, Adventek Fuel Systems, ARAI, Best Group, Dura Automotive, IBIDEN Co., Infineon Technologies, KYB-Conmat, Lucas TVS, Lumax Mannoh Allied Tech. Ltd., Minda Sai Ltd., Natesan Synchrocones Pvt. Ltd., Ramsays Corporations Pvt. Ltd., Ricardo (I) Pvt. Ltd., S.M. Auto Engineering Pvt. Ltd., TE Connectivity India, Tenneco Automotive, John Deere, and EKK Eagle Products.** Mahindra World City Club (MWC Club) organized the event to help ignite a passion for science and math.

The event commenced with lamp-lighting ceremony by the chief guest Arvind Balaji, Jt. MD of Lucas TVS. In his address he recognized the children for the courage to attend the event, demonstrate their skills and compete with the proper spirit.

Dr. Pawan Goenka, ED and Group President, Automotive and Farm Equipment Sectors, Mahindra and Mahindra Ltd. said, "We have always focused on education as one of our core corporate social responsibilities, as we believe that it ultimately leads to a better quality of life. Competitions like

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AWIM which convey the principles of physics and motion in such an innovative manner will go a long way in developing the engineering potential of the youth.”

Dr. Aravind Bharadwaj, President SAEINDIA and Sr. VP, Advanced Technology, Mahindra and Mahindra Ltd., said “SAEINDIA brought AWIM to India with an aim to encourage more school students to pursue careers in science and engineering. We hope this event will motivate the young kids to create global products in the years to come.”

Guest of honor Vishwanathan S., Director TE India, was amazed to see the energy levels showcased by the children. He said he was happy that such a novel initiative was run by SAEINDIA with the support of the industry and wished all the participating students great success.

Rajiv Modi, convener of AWIM welcomed the chief guest, guest of honor, the SAE fraternity, Mahindra senior leadership, sponsors, volunteers, teachers and all the participants. The children were overjoyed and fascinated when he referred to them as “young celebrities.” He acknowledged the initiative of SAEINDIA and the generous support extended by all the sponsors, calling the children “the future of our country.”

After the speeches by the guests, the inaugural ceremony was followed by a host of entertainment programs for the children. After the cultural program, Saurabh Chitnavis, Member EEB, SAEINDIA, provided technical rules for the Jet-Toy and Skimmer



Testing a skimmer submitted by one of the teams.



A team of judges with the skimmer entries.



SAE International team with SAEINDIA.



Jet-toy preparation.

challenges, presented the competition rules to the participants and answered various questions posed by the children.

On the competition’s second day, teams spent several hours preparing different models for different tests and exhibitions, including the presentation chart and a dream car. The toys were tested on the test track for performance criteria such as distance travelled, weight-carrying capacity, longest travel time, accuracy and speed. After their track tests was a presentation round in which teams were given a chance to portray their dream machine and explain details to a judging panel.

The panel was comprised of jurors from varied professions and diverse backgrounds and having a passion to engage in special initiatives like AWIM.

During the valedictory function, the event was joined by Dr. Bhaskar Ramamoorthy, Director, IIT Madras, as a chief guest and Dr. S. Thirumalini, Chair EEB, SAEINDIA, Velusamy R., Sr. VP - Engines and Components, Sanjay Deshpande, VP, Testing and Validation, and Virendra Gaikwad, Eaton.

The team from Saupins School in Chandigarh emerged as the overall winner in Jet-Toy Challenge and went on to participate at the SAE World Congress in Detroit, USA, in April. The Millennium School, Mohali, Punjab emerged as the overall winners for Skimmer Challenge.

Despite the rigors of the Challenge events, the children were ready the following day to visit Mahindra Research Valley in Chennai. They were thrilled to see the state-of-the-art research facility brimming with high-tech equipment, test rigs and test tracks and mesmerizing work environment.

Baja SAEINDIA takes place in Indore



Aerial view of Baja SAEINDIA 2016.



A competitor traversing part of the suspension-test course.

Passion, drive, motivation, zeal—and more—brought more than 8000 students from a variety of engineering colleges to compete in BAJA SAEINDIA this year. Nearly 400 teams were present at the virtual portion of the competition and 179 reached the grand finale.

The ninth edition of BAJA SAEINDIA concluded on February 21 and was followed by HR Meet, held in Pithampur Indore, where the darkened ground and the rolling hills come together to become a very capricious track. On the outskirts of Indore, the NATRIP facility hosted the BAJA event, where students from all over the country brought their ingeniously-built BAJA buggies for testing and judging.

This year, the teams were given a new track with natural hurdles spread over

five kilometers, thus making it more challenging both for the vehicle and the drivers. This year, students once again also created electric buggies for the eBAJA event, the second time in which the Baja competition aimed to provide a platform to leverage the onset of electric mobility in India. While the conventional BAJA event is all about petrol-driven ATVs, eBAJA vehicles are propelled by electric motors powered by rechargeable lithium-ion battery packs. The eBaja event saw participation from nine colleges and the “Best eBAJA Team” award was won by **Smt. Kashibai Navale College of Engineering, Pune**.

Compared with last year’s Baja competition, a greater number of teams were able to complete the endurance

course in the main BAJA event, despite competing on a track which was tougher than the previous year. Team Nemesis from the **College of Engineering, Pune**, claimed the overall win in BAJA SAEINDIA 2016. Apart for the overall championship, the Nemesis team received nine awards, while **Alard College of Engineering, Pune** and **SRM University, Chennai**, respectively grabbed the second and third positions.

If the trend for this challenging and enjoyable event continues, next year’s BAJA competition promises to be bigger and grander. Ravi Kharul of **Endurance Technology** is the convener for BAJA SAEINDIA 2017, scheduled for Feb. 16-19, 2017 and will be followed by HR Meet on Feb. 20-21, 2017.



Mrs. Rashmi Urdhwarshre, director, ARAI and chief guest, and Sunil Chaturvedi, CEO, ASDC and guest of honor during the inaugural ceremony.



Team Nemesis from the College of Engineering, Pune, winner of Baja SAEINDIA 2016.

SAE International Mobility Conference held in New Delhi

SAEINDIA, in association with SAE International, in February organized the ninth edition of SAEINDIA International Mobility Conference (SIIMC) with the theme “Safe Synergetic Sustainable Mobility Technologies for Future.” The event, held at the India Habitat Center in New Delhi, focused on key technology issues relevant to mobility engineering such as safety, design, information technology, electronics, fuels and environment.

The conference was inaugurated by Dr. Rajan Katoch, Secretary, Department of Heavy Industries, Government of India; also in attendance were Dr. Aravind Bharadwaj, President, SAEINDIA; Arvind Balaji, President, ACMA and Jt. MD, Lucas TVS; S. Sandilya, Past President, SIAM and Chairman, Eicher Motors; Dr. R.K. Malhotra, Sr. VP, SAEINDIA; and C.V. Raman, ED – Eng., Maruti Suzuki India and chairman of the SIIMC 2016 organizing committee.

In the inaugural session, several key points were discussed by the dignitaries:

- The outlook for Indian auto industry.
- Challenges of urbanization and sustainable mobility, stringent safety regulations and emission norms (BS VI by 2020).
- The need to develop technologies relevant to India.



Dr. Rajan Katoch, secretary, Dept. of Heavy Industries, begins the conference.



Dignitaries present for the inauguration.

The organizers received a total of 400 papers from R&D engineers from vehicle and component manufacturers. Under a rigorous SAE International process of review, a total of 91 papers, including 22 student papers, were selected for presentation during the three-day event. In all, 17 technical and five student sessions were held, in addition to 11 keynote presentations.

Another highlight of this year’s conference was a TOPTECH program on crash safety conducted by Dr. Joseph Kianthra, former Associate Administrator at NHTSA in the U.S. The conference also had interesting and relevant keynote presentations and panel discussions on electric vehicles, the fuel cell future, connected vehicles and Advance Driver Assistance Systems (ADAS), automotive lighting and light-signaling technology,



Team SIIMC 2016.

automotive safety, advancing safety in a connected mobility environment, Clean Air 2020 and others, all presented by national and international experts.

The conference also comprised 22 technical sessions chaired by leaders from the automotive industry and separate student sessions that brought out the brilliance of authors on wide variety of industry-related issues.

The conference's cultural event was appealing to the eye and intellect of the audience, which was treated to a fascinating show of talented artists. There were approximately 25 exhibitors that showcased the latest advances and innovations in the industry and SIIMC 2016 made a record contribution to the All-India Confederation of the Blind (AICB) by converting the cost of traditional guest mementos into donation.



Dignitaries present donation to representatives of All-India Confederation of the Blind (AICB).

SAEINDIA celebrates 20th anniversary in March

March 18, 2016 was a special day at Hotel Le Royal Meridien in Guindy, Chennai, as SAEINDIA celebrated its 20th anniversary. It was a grand assembly of past and present, old and young and next-generation leaders from India's automotive industry.

The Chairman of Infosys and Executive Vice-Chairman of Ashok Leyland, R. Seshasayee, served as chief guest and Dr. Pawan Goenka, the prime architect of SAEINDIA, also was there to lend the evening a festive flavor.

Dr. Aravind Bharadwaj, current President of SAEINDIA, welcomed the gathering and briefly walked down

memory lane to touch on the significant events of the organization's first 20 years—and in particular the new programs and events organized in the last two years.

Dr. Bharadwaj was followed by a special rendezvous discussion with past presidents of SAEINDIA, where conversation ranged on variety of issues including road engineering and traffic



A discussion with SAEINDIA past presidents, moderated by Sumantra Barooah of Autocar Professional.



Dr. Aravind Bharadwaj, President of SAEINDIA.



A coffee-table book, "The SAEINDIA Growth Story—Journey of Two Decades" was distributed by the chief guest.

SAEINDIA

News



**R. Seshasayee,
Chairman of the
Board of
Directors.**

management, technology providers and innovators, and skills development for ready employment and certification programs to enable engineers' absorption into the auto industry. Some also recalled the history and challenges SAEINDIA faced in its formative years—issues they said have turned into opportunities for growth and development.

Mr. Seshasayee, the chief guest, compared the growth of the automotive industry to human evolution over a

millennium: the transformation taking place with driverless connected vehicles, he said, is like the billions of neuron cells in the human body connecting the functions and activities with minute and meticulous precision. He also touched upon the parasitic and thermal losses in internal-combustion engines that have yet to be overcome, comparing the situation with the internal organs in a human body that have evolved significantly to become highly efficient and effective.



**Dr. Pawan
Goenka.**



**Prof. T.R.
Jagadeesan, former
Executive Director
and advisor,
SAEINDIA, sharing
his experiences
with SAEINDIA.**



A brochure on FISITA World Congress 2018 was released to kick off the launch of the anniversary program and copies were distributed to the members on the dais.



Past Presidents of SAEINDIA: Dr. K. Kumar, Dr. R. Mahadevan (2004-2005), Dr. Pawan Goenka (2006-2007), M.S. Kumar (2008-2009), R. Dayal (2010-2012), S.R. Marathe (2012-2014), recognized with a special memento.

SAEINDIA Aero Design Challenge takes off

SAEINDIA Southern Section conducted its Aero Design Challenge in March at the Rotor Association of Model Aircraft (RAMA) Flying Field and at **Hindustan Institute of Technology and Science (HITS)**, Chennai.

The SAEINDIA Aero Design Challenge is an annual collegiate competition series launched by SAEINDIA Southern Section for the first time in 2015. The SAEINDIA event follows Aero Design Challenges first established in the U.S and Brazil and incorporates three separate phases: design report submission by the teams, flying prototype radio-controlled aircraft at a UAV airfield and oral design presentations.

The competition is conducted for micro- and regular-sized radio-controlled aircraft. In the micro category, student teams design an electric RC aircraft with high payload lifting capability with the constraint of minimum empty weight. In the regular-sized category, teams design an internal combustion-powered RC aircraft with a maximum six-

foot wingspan. Seventy-five students representing 40 teams from 30 different institutes across the nation successfully completed the competition.

An aero modelling workshop was conducted for all the teams to help facilitate fabricating their conceptual design. The workshop was conducted at HITS-Chennai, **KCE-Coimbatore** and **MLRIT-Hyderabad**. All the teams attended the workshop and acquired knowledge required for aircraft design and fabrication and, interestingly, the workshop also helped most of the micro-craft teams to fabricate their conceptual design.

Later, SAEINDIA Aerospace board representatives interacted with the students and selected ten students from various institutes to represent the Indian aeronautical education sector to the SAE International Aerospace Board during the event.

This February, the student design reports were collected from registered teams and evaluated by academic volunteers from **MIT**, **IIT** and from other Indian institutes. The



SAEINDIA Aero Design Challenge takes off.



Some of the prototype flights.

Para-motoring by the RAMA Flying Field team.



P.H.Narayanan CEO, UCAL fuel systems, presents the chief guest address as C.S. Karunakaran, Technical Officer HITS and champion, SAEINDIA Southern Section, looks on.



The chief guest, Dr. Ponramalingam, Registrar, HITS, is presented with the Academic Partner memento.

SAEINDIA

News

Welcome address
by Parvez Alam,
COO, UCAL-JAP.



final event was held in March.

T. Kasiraja, MC member, inaugurated the flying competition and champion C.S. Karunakaran explained the judging criteria in the presence of field judges. The student teams flew their prototype aircraft in mid-March at a private airfield owned by RAMA near Achirapakkam, Kancheepuram. A para-motoring show also was conducted by the RAMA Flying Field team.

Design judges conducted a technical inspection during the airfield flying session to ensure the prototypes were built according to each team's submitted design report.

Following the flying sessions, oral design presentations took place at HITS, Chennai. The presentations detailed how the flight performance of the prototype aircraft aligned with the design report analysis.

In the micro- and regular-size categories, the best three teams were selected for the best presentation award, best flight award and best report award.



Aero Design Challenge winning team.

In the regular-size category, Aero Unwired won first prize, Lightning Hawks won second prize and Sky Racers won third prize.

In micro-size category the following team Jatayu won first prize, Flying Hawks took second prize and Aeroblades won third prize.

A total of 39 national awards were won by 25 teams that took place in the Aero Design Challenge. National aviation analysts called the competition a milestone in Indian aviation education, saying the event is the first of its kind to showcase the institutional and industrial strength of Indian aviation.

The chief guest for the valediction was P.H. Narayanan, CEO, UCAL Fuel Systems and Dr. Ponramalingam, Registrar, HITS and other dignitaries shared the dais with the chief guest. During his speech, Narayanan said the event had given Indian aviation students a chance to realize their potential and he acknowledged the support of the SAEINDIA Southern Section leaders, management of HITS-Chennai and RAMA flying field.

SAEINDIA hosts first SAE Board of Directors meeting in 2016

In its first of three meetings scheduled for 2016, the SAE Board of Directors convened in Chennai on Jan. 23. The meeting offered an opportunity for Board members to experience various aspects of SAE International's strategic involvement in the important India market.

In addition to addressing SAE business matters (including the swearing in of new Board officers and members on Jan. 21-22. The trip to India saw three separate Board delegations participating in technical visits organized by three regional sections on Jan.20:

- Commercial vehicle: Hosted by Western India Section in Pune (John Deere Technical Centre and Automotive Research Association of India, Arai).
- Aerospace sector: Hosted by the local section in Bangalore (Boeing and key government organizations).
- Automotive sector: Hosted by Southern India section in Chennai (Mahindra Research Valley, Renault/Nissan).

Technical visits in the three regions included manufacturing and research facilities. Additionally, there were technical panels



SAE officers and board members pose with SAEINDIA officials at the conclusion of the SAE Board of Directors business meeting in January.

and presentations, with some involving young engineers as key members of the audience. In the evening, the local host section organized a special dinner with the broader technical community.

-Submitted by Terri Anzaldi, Administrator, SAE Board of Directors

Honeywell partners with Indian manufacturer on low-GWP auto refrigerant

Honeywell has entered into a supply agreement and technology license with an Indian manufacturer to produce Honeywell Solstice yf, an automobile refrigerant with a global warming potential (GWP) of less than 1. Honeywell will license its proprietary process technologies to produce the refrigerant to **Navin Fluorine International Ltd (NFIL)**, which will manufacture Solstice yf in India exclusively for Honeywell. Small-scale production is expected to begin by the end of 2016.

Honeywell says it is committed to meet growing demand through a robust global supply infrastructure. Honeywell and its key suppliers are investing approximately \$300 million to increase global production capacity for Solstice yf, including the construction of a new, world-scale manufacturing plant using new process technology at the company's existing Geismar, Louisiana, U.S., refrigerants manufacturing site.

"More than 8 million cars on the road today safely use



Honeywell Solstice yf, also known as HFO-1234yf, is a next-generation hydrofluoro-olefin (HFO) refrigerant that is a near drop-in replacement for R-134a, a hydrofluorocarbon (HFC) with a GWP of 1,300.

Solstice yf. That number is expected to grow to more than 18 million cars by the end of 2016. This agreement reflects our commitment to delivering the supply chain reliability and security that customers can rely upon as they transition to next-generation products that are safe to use, available today, and capable of making a significant

positive environmental impact," said Ken Gayer, Vice President and General Manager of **Honeywell Fluorine Products**.

"Honeywell's supply agreement with NFIL, one of India's largest manufacturers of specialty fluorochemicals, represents a first step in our commercial relationship that will help us to meet growing global demand for Solstice yf."

Solstice yf, also known as HFO-1234yf, is a next-generation hydrofluoro-olefin (HFO) refrigerant that is a near drop-in replacement for R-134a, a hydrofluorocarbon (HFC) with a GWP of 1,300, for use in vehicle air-conditioning systems globally. Solstice yf is also being used in a growing number of stationary air conditioning and commercial refrigeration applications. The demand for Solstice yf for use in mobile air conditioning is increasing rapidly due to increased global environmental regulations and policies aimed at reducing the global warming impacts of HFCs.



Small-scale production of Solstice yf in India is expected to begin by the end of 2016.

Mahindra's new Blazo series includes haulage, tractor-trailer, and tipper models, and is equipped with FuelSmart multi-mode drive technology.



Mahindra launches new Blazo heavy-truck series with FuelSmart multi-drive

Mahindra Truck and Bus Division (MTBD) recently launched its new heavy commercial truck series under the brand name **Blazo**. The Blazo series includes haulage, tractor-trailer, and tipper models, and is equipped with FuelSmart technology, the highlight of which is the introduction of a 7.2-L CRDe engine coupled with a multi-drive mode that is typically reserved for passenger cars, the company notes. The multi-mode feature includes three modes—Turbo, Heavy, and Light—which can be controlled by the driver via switches according to the load and road conditions. The new series also receives a re-freshed design and introduces the new turquoise blue color variant.

MTBD is making two guarantees to buyers of the new Blazo series: better fuel efficiency than customers' existing trucks or else the truck can be returned, and uptime on its breakdown service by getting the truck back on road in 48 hours or the company will pay the customer Rs. 1000 per day.

"At the core of the mileage guarantee that we are offering for the Blazo series of trucks is the FuelSmart technology of our mPower CRDe engine," said Rajan Wadhera, President & Chief Executive - Truck & Power Train, and Head - Mahindra Research Valley, Mahindra & Mahindra Ltd. "In commercial vehicles there is a challenge to provide a single solution of engine and vehicle powertrain configuration to multiple applications and variants. The FuelSmart technology, with its multi-mode switches, will help drivers in choosing the correct mode based on load and road conditions, thereby leading to efficiencies."

Nalin Mehta, Chief Executive Officer, Mahindra Truck and Bus Division, said, "The service guarantee is the outcome of our strong focus on after-sales network by leveraging group synergies and organic growth in the service touch points and spares retailer network."

Specs on individual models can be found at <http://www.mahindratruckandbus.com/blazo.html>.



The multi-mode feature includes three modes—Turbo, Heavy, and Light—which can be controlled by the driver via switches according to the load and road conditions.

Industry NEWS

Vistara deploys SITA AIRCOM and network technology

SITA and SITAONAIR have completed the joint implementation of aircraft communications, airline operations, and network connectivity for Vistara, the joint venture between Tata Sons Ltd and Singapore Airlines Ltd. The successful deployment, completed within 16 weeks, supports Vistara's expansion plans. Vistara started flying in January 2015 and has 307 flights each week, across 12 destinations in India. The carrier has nine Airbus A320s in its fleet.

Vistara is SITAONAIR's first AIRCOM FlightPlanner solution customer in India. The technology provides computerized flight plans and data such as inflight weather updates and airport information. The result is route planning that reduces operational costs, improves on-time performance, and facilitates safer and smoother flights by avoiding major weather events.

The airline uses SITA's global IP network to connect its back offices, ticketing desks, and check-in counters at airports across India with its passenger services system, based in Germany. The network handles both reservations and departure control services and it is specifically tailored to be scalable to support Vistara's future expansion in India. Vistara also uses SITA's Type B Messaging Service for critical air transport industry operational messages.

SITAONAIR's AIRCOM Datalink services, FlightMessenger, and FlightTracker are other solutions used by Vistara to manage air-to-ground communications for the flight crew, airline operations and air traffic controllers, and to track their aircraft.



Vistara is SITAONAIR's first AIRCOM FlightPlanner solution customer in India. The airline also uses SITAONAIR's AIRCOM Datalink services, FlightMessenger, and FlightTracker (pictured).

SITAONAIR's VHF network, the largest in India, provides the connection between the aircraft and the ground.

"Indian aviation has an immense growth potential," said Phee Teik Yeoh, CEO of Vistara. "This will be one of the world's largest aviation markets within the next five years and Vistara has a prominent role to play in that expansion. We are putting all the right tools in place to make sure we are best positioned to leverage the growth opportunity. The efficient communication and network technology that SITA and SITAONAIR have delivered are both essential for smooth operations and facilitating our expansion."

ZF TRW to launch Electric Park Brake in India, production starts in 2017

ZF TRW recently announced through its joint venture, Brakes India Ltd, that it has won the first business award for its Electric Park Brake (EPB) system in India. Launching with a major global vehicle manufacturer, the technology will start production in 2017, marking the first launch of its kind for the Indian market,

the supplier claims. In addition to providing park brake functionality, EPB is a fully integral part of the brake system with features such as dynamic actuation and brake pad wear sensing, and reduces the degradation associated with mechanical systems. The EPB also helps enhance safety in emergency situations with full four-wheel anti-lock functionality versus standard park brake that provides emergency braking only on the rear axle.



The Electric Park Brake (EPB) is typically fitted on rear axles, but ZF TRW's latest actuator generation can be also installed on front axles for different vehicle layouts.

Manfred Meyer, Global Vice President, Braking Engineering, said: "ZF TRW was first to market globally with its EPB system in 2001 which pioneered with Lancia, Audi, and VW and more recently on the BMW X4 and i8, Jeep Renegade, Fiat 500X, Ford F150, Honda Accord, Nissan Qashqai, Land Rover Range Rover Evoque, and more. We have now produced more than 65 million units...With our vast experience and global footprint, we are ideally positioned to bring the performance and safety benefits of EPB to all vehicles and in all regions."

ZF TRW offers a range of EPB solutions including standard EPB, integrated EPB which removes the requirement for a separate electronic control unit (ECU) due to its integration with the electronic stability control (ESC) system, and EPB for front axles which can help to make the technology more suitable for smaller vehicle segments.

Badri Vijayaraghavan, Executive Director, Business Development, Brakes India, said: "India will continue to be dominated by small cars with rear drum brakes. The offering of a front EPB opens up a wealth of opportunity regarding EPB installation due to its packaging and performance benefits."



AUTOMOTIVE POWERTRAIN

Clutchless hybrid transmission concept for high-performance cars



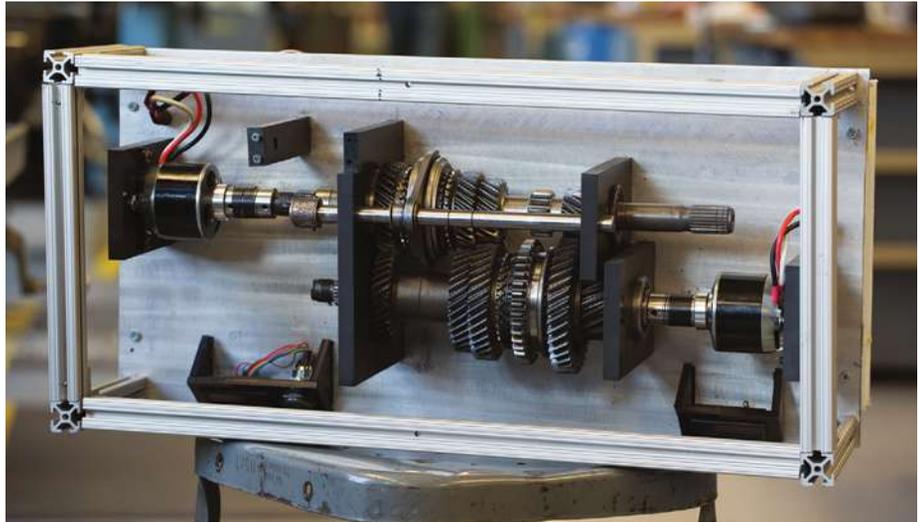
Dan Dorsch with his clutchless hybrid transmission for high-performance cars. His college projects have led to a number of inventions, including an underwater biomimetic burrowing device known as the RoboClam, for anchoring autonomous underwater vehicles. (Lemelson-MIT Program photo)

An MIT student-inventor's clutchless hybrid transmission concept aims to provide high-performance vehicles an energy-saving attitude without compromise.

The concept mechanism uses an electric motor to fill the acceleration lag that occurs when a driver releases the throttle and engages the clutch. A second electric motor is used for quickly speed-matching the gears during the shift since there is no mechanical means to speed up the next gear before engaging it.

"Right now, we are only at the proof of concept stage," Dan Dorsch told *Automotive Engineering*. "There is quite a bit of work left in order to develop the transmission into something that can be used on a production car."

Dorsch, 26, is a second-year Ph.D. candidate and a **National Science Foundation** Graduate Research Fellow in the mechanical engineering program



Concept transmission showing the speed-matching functionality that allows for clutchless gear shifting. (Lemelson-MIT Program photo)

at the Massachusetts Institute of Technology. His invention earned him \$15,000 as the 2016 Lemelson-MIT "Drive it!" Graduate Student Prize winner. The competition is funded by Portland, OR-based **The Lemelson Foundation** and administered by MIT's School of Engineering.

Many current high performance production cars rely on a dual-clutch transmission, including those with a hybrid-electric powertrain. Two current examples are the plug-in hybrid **Porsche 918 Spyder** with a 7-speed PDK dual clutch transmission, and the hybrid **Ferrari LaFerrari** with a 7-speed dual clutch automated manual.

Innovations that can maintain or improve vehicle performance and increase fuel economy quickly attract the attention of the industry's engineering management. According to Devin Lindsay, **IHS Automotive's** Principal Analyst for North America Forecast, "Even high performance cars are not immune to fuel economy regulations."

Weight reduction was one of Dorsch's design bogies.

"The lightweight aspect is due to removing the double clutch, including the fluid that often fills the clutches," he said. "And since high performance cars often have one to two motors for performance

reasons, we can use the motor or motors in the powertrain to replace the function of the clutch."

Dorsch's MIT research advisor and two student teams assisted with the project's development. Two concept prototype architectures were built, each lasting about four months from design to hardware. **The MathWorks'** MATLAB models show how the transmission is likely to perform.

"We have also analyzed different driving scenarios based on a specific powertrain configuration," said Dorsch.

Transitioning the concept transmission to a testing phase is likely to unfold with a European high-performance vehicle OEM that he would not identify. Said Dorsch, "It's possible that lab testing on a prototype concept transmission with this OEM could happen as early as 2017."

Dorsch has filed a patent application on one of his transmission designs. He said the provisional patent describes the overall architecture, its functionality, and the driving modes.

A patent application will be filed in the coming months for the second design. "This design uses a single electric motor whereas the patent-pending design uses two electric motors," he said.

Kami Buchholz

TECHNOLOGY Report

OFF-HIGHWAY POWERTRAIN

Perkins takes modular approach to new Syncro 2.8- and 3.6-L engines

Perkins launched a new family of 4-cylinder, 2.8- and 3.6-L diesel engines that deliver 60 to 134 hp (45 to 100 kW). Citing modularity as a key element of this new engine platform, Ramin Younessi, President of Perkins, unveiled the Syncro 3.6-L engine in the company's booth at Bauma 2016.

"This year's Bauma is the biggest yet, so it's important for us to take this opportunity to launch one of the most important product launches for us in the past 20 years," he said. "This is a modular engine approach that offers the best solutions for global OEMs by reducing complexity, simplifying installations, enabling them to have one machine platform serving global markets."

Mark Stratton, who serves as General Manager - Medium Engines at Perkins, sees a promising future with significant benefits to their customers and entire value chain as a result of the modular approach and strategy. "From a customer perspective, it's critical in terms of mounting points and interfaces and those types of things, but from a design standpoint, from an engineering standpoint, obviously it lets us leverage our engineering span across a much wider portfolio of products," he said.

Stratton continues, "Another critical piece of it that we find is in our quality control and capability side. Think about the validation we've got to do, so every piece that I can make common, then I'm collecting good quality data whether I'm running it for this wheel loader customer, for this electric power customer, this guy in a welder—all that gives me better data. So you can shorten the validation time and actually have a much more robust validation plan if you don't have different configurations for every component.

"The other piece for us, because I answer for the manufacturing side of the business, clearly it's much more efficient for the supply chain to have as much commonality as you can. It's much more efficient for your operations, your physical facilities, your assembly groups, your documentation. Then the other half of the business, working with the dealers, the service and support side, the amount of inventory they have to carry, the specialization they have to have, the types of tools they have to



The Perkins Syncro range of common-rail engines meets multiple global emissions standards including EU Stage V and U.S EPA Tier 4 Final. The lineup is engineered to integrate into more than 80 different machine models.

use, so that commonality carries value for us from the customer all the way through the engineering, through the factory, through production, through distribution and through the life-cycle of the product. So for us it's a fundamental tenant for how we expect to design engines and how we want to make them in the future."

Technical specs, compliance, and manufacturing

The Perkins Syncro range of common-rail engines meets multiple global emissions standards including EU Stage V and U.S EPA Tier 4 Final. Engineered to integrate into more than 80 different machine models, the company believes these new engines deliver the performance, value, and reliability its customers expect to help them access new markets and support their business growth.

The high power and torque density provides OEMs the opportunity to move to smaller, more compact engines. The improved fuel consumption, quicker response, and electronic integration that end users need to differentiate their machines is achieved through an increase in power density of 22% when downsizing.

With up to an 8% improvement in fuel economy during machine use, the 3.6-L offers power up to 134 hp (100 kW) with up to 370 lb-ft (500 N-m) of torque, while the 2.8-L turbo after-cooled variant delivers a maximum of 74 hp (55 kW) with up to 240 lb-ft (325 N-m) of torque.

The Perkins Syncro range benefits from a suite of technologies including a common-rail fuel system, electronic control, advanced air systems, and aftertreatment configurations. A 90% commonality in the customer interfaces between the 2.8- and 3.6-L engines offers OEMs the freedom to determine machine platform strategies that suit their businesses and markets.

"The recent advances in fuel systems, control systems, predictive engineering, and aftertreatment ensures our new 2.8-L and 3.6-L engines are the right solution for off-highway machines like wheeled loaders, tractors, telehandlers, and excavators," said New Product Manager Allister Dennis. "We've now started work on this family of engines to give us and our customers plenty of development and field validation time before Stage V introduction."

The engine's modular design ensures ease of integration into existing—and future—generations of machines.

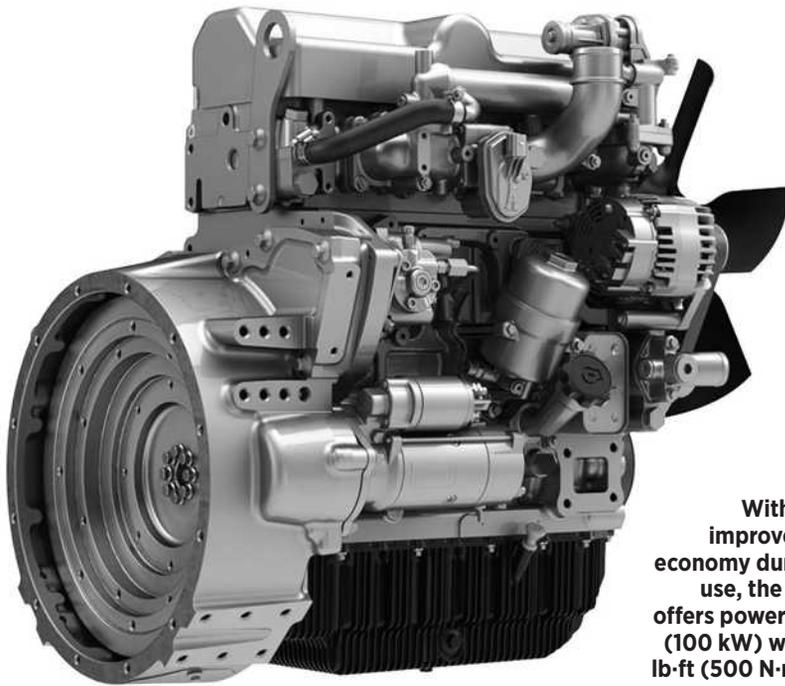
AEROSPACE PROPULSION

Ground testing begins on the GE9X

In mid April, ground testing began on the first full GE9X development engine at GE Aviation's Peebles Testing Operation in Ohio. The GE9X engine will power Boeing's new 777X aircraft. According to Bill Millhaem, General Manager of the GE90/GE9X engine programs at GE Aviation, "The ground testing will generate data on the full engine system and aerodynamic performance, mechanical verification, and aero thermal system validation."

Maturation testing of the GE9X turbofan engine began about five years ago and has progressed from component-level all the way to the recent first full engine to test (FETT). FETT brings all the GE9X technologies together to demonstrate their operability as a complete propulsion system.

The GE9X FETT began just six months after the engine's design was finalized, which is much earlier in the development process compared to most other engine programs. GE says



With up to an 8% improvement in fuel economy during machine use, the 3.6-L engine offers power up to 134 hp (100 kW) with up to 370 lb-ft (500 N-m) of torque.

"Stage V is an important area of focus for Perkins and part of an increasingly complex range of emission standards across the world," said Product Concept Marketing Manager Oliver Lythgoe. "OEMs want to sell machines in multiple regions to support business stability and growth, but the costs of designing a different machine for each region is unsustainable. Our range of 2.8-L and 3.6-L engines have been designed as a modular product, so versions of the engine for different emissions standards and fuel specifications can be used with the same installation and, critically, the same engine performance and machine integration."

Manufacturing will start on a proven production line in Peterborough, U.K., and Perkins is developing the capacity to manufacture the Perkins Syncro range in facilities in the Americas and Asia. The company says this multi-region production capability will provide OEMs short, consistent lead times and the business stability they value.

As many machines in this power band enter the rental sector, the need for good value, compact, and reliable engines have been among the project's primary requirements. A number of key performance features have been included, as Lythgoe explains: "High power and torque and fast response are key enablers for engine downsizing, and can help OEMs deliver machines that are easy to operate. Other features allow us

to achieve significant fuel savings in the areas of the power curve where real machines spend most operating time."

The range has flexible aftertreatment options for both displacements, with an array of engine and off-engine mounted options for optimized packaging in all machines. "Our aftertreatment system has seen a 40% reduction in package size, as it benefits from the latest technologies and design principles," said Dennis. "We've leveraged the extensive diesel particulate filter (DPF) and selective catalytic reduction (SCR) system experience gained over the last five years and believe a compact two-stage system will provide our customers with the most flexible package solution for all emissions standards, plus common installation and manufacturing benefits."

Chris Snodgrass, Vice President, Global Sales, Marketing, Service and Parts at Perkins, concluded by sharing that the "modular design allows us to have one single engine family that has two important displacements.

Modularity allows us to reduce complexity and leverage our scale and simplify OEM chassis installations. We also focused on some other key principles. Compact size and machine installation flexibility...strong performance, enabling our customers to downsize engines in their highly integrated machines, and industry-leading reliability and durability in real-world high load applications."

Greg Muha



Aircelle's exhaust systems will equip the 777X's two GE Aviation GE9X turbofan engines, providing the benefits of lower mass, along with increased resistance to heat with the use of Aircelle processes for titanium high-temperature applications. These exhaust systems are among the largest of their type ever produced for civil aircraft, and include acoustically treated areas for a reduced noise level signature. (Aircelle: Patrick Boule)

TECHNOLOGY Report



With a 235-ft wingspan, Boeing's twin-engine 777X twin will offer advantages in both fuel consumption and operating costs per seat. Because of their carbon-fiber composition, the wings are both strong and flexible—and the tips will fold up so airports can accommodate their wider span.

this timing assures that everything learned from FETT will be captured in the certification engines. Next year will see the GE9X program starting certification testing and flight testing on GE Aviation's flying test bed. Engine certification is anticipated in 2018.

IHI Corporation, Snecma and Techspace Aero (Safran), and MTU Aero Engines AG are just a few of the participants in the GE9X engine program

Another Safran company, Aircelle, is supplying titanium engine exhaust systems for the 777X, marking its first major role as a supplier to Boeing. The exhaust system is being used as part of



Aircelle (Safran) began the manufacturing of engine exhaust systems for Boeing's 777X with the laser cutting of a titanium sheet at its Le Havre, France production facility, performed in the presence of Boeing representatives from the 777X program's nacelle, supplier management, and engineering functions. This first exhaust system will be used as part of the overall engine development program in partnership with Boeing and GE.

the overall engine development program in partnership with Boeing and GE. These exhaust systems are among the largest of their type ever produced for civil aircraft, and include acoustical treatment areas, also of titanium, for a reduced noise level signature.

The exhaust systems on the two GE9X engines offer both mass efficiencies and increased resistance to heat primarily as a result of Aircelle's processes for titanium high-temperature applications. Aircelle has optimized the design and manufacturing of titanium nacelle components, applying its expertise and proprietary database in defining and validating the metal's performance for exhaust systems. The company has invested in new and upgraded production resources for the 777X program, while also working with Boeing in ensuring routines and procedures are fully compliant with its production requirements.

With almost 700 GE9X engines on order, the GE9X engine will be in the 100,000-lb thrust class and will have a large front fan 134-in in diameter with a composite fan case and 16 fourth-generation carbon fiber composite fan blades. Other key features include a next-generation 27:1 pressure-ratio 11-stage high-pressure compressor; a third-generation TAPS III combustor for high efficiency and low emissions; and CMC material in the combustor and turbine.

Jean L. Broge

AUTOMOTIVE POWERTRAIN

V-CR, water injection, new EGR methods top SAE engines symposium

Powertrain experts detailed the technologies they see as most promising to enable light-vehicle engines to meet global CO₂ regulations through 2025, at the 2016 SAE High-Efficiency IC Engines Symposium in Detroit. The list includes growing use of the Miller and Atkinson thermodynamic cycles, cooled EGR, and water injection, all of which are currently in production.

And progressing rapidly due to greater industry development focus and investment are a new range of high-octane fuels, various methods of waste heat recovery, variable compression ratio (V-CR) systems, divided exhaust boosting, and dedicated-EGR (d-EGR). The latter technology employs one or more of an engine's cylinders for mixing a high octane hydrogen-and-carbon-monoxide reformat for recirculation (at rates up to 25%) back into the combustion chambers.

Now in development at Southwest Research Institute (SwRI), d-EGR enables the highest possible (over 12:1) compression ratios and ratio of specific heats—two key metrics for optimum engine efficiency—within a significantly expanded knock/stability window. In-vehicle testing using a turbocharged Buick Regal has demonstrated claimed city and highway fuel efficiency improvements of 13% and 9.2%, respectively, with NO_x + NMOG emissions (31 mg/mi) at virtually LEV3 levels and a 1-s improvement in 0-60 mph acceleration.

"Improving engine efficiency is hard; we struggle to achieve 1%—and there is no Moore's Law for engines," noted Dr. Terry Alger, Director, Engine & Vehicle R&D, Engine, Emissions & Vehicle Research, at SwRI. Dr. Alger kicked off the two-day symposium, now in its seventh year, which precedes the SAE World Congress. He asserted that despite test drive cycles being not representative of real-world vehicle use, the industry "must optimize engine emissions outside those cycles to really clean the air"—while delivering customer-pleasing performance.

According to **BorgWarner** CTO Chris Thomas, who closed the day's session with a provocative look at how to predict automotive powertrain's future, an exceptionally efficient gasoline engine today that is claimed to achieve 42% brake thermal efficiency (BTE), actually averages only about 30% BTE across the vehicle fuel-economy cycle. So much work needs to be done in optimizing the powertrain within the overall vehicle.

ORC for heat, energy recovery

During the first-day (April 10) meeting, engineers and researchers from **Bosch**, **FEV North America**, **IAV Automotive**, the **New A.C.E. Institute** in Japan and **BorgWarner**, in addition to **SwRI**, said the advanced technologies in the pipeline will mostly be optimized as systems. These "bundles," as some called them—one combination might be a Miller cycle engine with variable compression ratio, Organic Rankine Cycle waste heat recovery, and water injection, for example—are vital for achieving vehicle fuel consumption reductions averaging 6% per year.

Such aggressive progress cannot be achieved, the SAE experts agreed, without powertrain electrification, in order to hit the EU's mandated 95 g CO₂/km fleet target in 2020 and the U.S. 2025 CAFE, said Marc Sens, Department Head of Thermodynamics and Boost Systems at IAV.

The Organic Rankine Cycle (ORC) is a closed-loop thermodynamic process where heat is transferred to a fluid at a constant pressure. The fluid is vaporized then expanded in a turbine or piston-type expander to drive a generator, producing electricity. The spent vapor is condensed to liquid and recycled back through the cycle. Sens noted typical exhaust gas energy losses of 32% that can be harvested. He reported that IAV is developing a mechanical ORC that features two heat exchangers along the engine's exhaust manifold and a 250-cc piston expander. The ORC produces 9kW, he said.

H2O injection and variable CR return

Water injection, a decades-old technology first proven in WWII fighter aircraft and later in racecar engines for mitigating



Dr. Terry Alger of SwRI detailed his team's development of Dedicated EGR at the 2016 SAE High Efficiency IC Engines Symposium on April 10. (Lindsay Brooke)

combustion knock and thus enabling higher compression ratios (<http://articles.sae.org/14176/>), is now in active discussion in production-vehicle circles. Both IAV and Bosch experts highlighted their companies' work in this increasing-ly viable area.

Li Jiang, Director of Advanced and Systems Engineering at Bosch and holder of 14 patents, noted that "the real efficiency of water injection is unlocked by higher compression ratios." But she admitted that a typical system adds mass and requires a fairly extensive bill of material, including a unique double-acting pump needed to draw water out of the lines and tank to avoid freezing in cold ambient temperatures.

There's also the not-insignificant issues of added cost and of where to source the system's water: from the onboard tank (tap water or distilled), or from A/C system condensate, or from



FEV North America's Rob deBrujin discussed variable compression ratio engine designs. (Lindsay Brooke)



Li Jiang of Bosch covered the benefits and challenges of water injection systems. (Lindsay Brooke)

exhaust-gas condensate. Liang reported an extensive Bosch customer survey, conducted with over 3000 people in the U.S. and Germany, regarding acceptance and expectations of a vehicle water injection system and proposed refill intervals.

Variable compression ratio engines are another technology that has been investigated and prototyped for decades, and one that again is under development focus, the SAE experts noted. Both Marc Sens of IAV and Rob deBrujin, Director of Gasoline Engines at FEV North America, showed data on the benefits of V-CR for improved knock resistance with a variety of fuels, combustion stability, and significant fuel-economy gains. V-CR technology works best with long-stroke (1.3 to 1.4:1 bore/stroke ratios), according to Sens.

FEV's deBrujin detailed his company's novel 2-step V-CR featuring a sophisticated and complex connecting rod design. He said the set-up has been tested to 200 bar (2900 psi) peak firing pressure.

Divided exhaust boosting (DEB) is a BorgWarner concept presented by CTO Chris Thomas. DEB is an elegant, efficient, and relatively low cost strategy of bypassing the turbocharger using bifurcated exhaust ports and a series of valves that direct exhaust gas directly to the aftertreatment catalyst. The concept enables faster cat light-off, use of a smaller turbine, and an 18° shift in the knock limit at 4000 rpm wide-open throttle, among other benefits.

Lindsay Brooke

AUTOMOTIVE ELECTRONICS

Next-gen electronic controls: Open source, scalable and integrated



Integrating electronics to create multi-domain controls was touted by Michael Groene of Delphi at the 2016 SAE Congress panel on vehicle electronics.
(Terry Costlow)

All trends point to rapidly increasing levels of vehicle electronics. That's forcing engineering managers to explore ways to consolidate hardware and improve software development while they adjust internal staffing and forge tighter alliances with customers and suppliers.

A range of strategic and tactical changes were discussed by panelists during the session "Are Functions and Software Becoming More Important than Hardware in Vehicle Electronics Engineering?" during the 2016 SAE World Congress. They also took a few minutes to answer that question.

"If you look at key performance indicators, software allows more ability to differentiate," said Stephan Tarnutzer, Vice President of Electronics at FEV.

For the most part, panelists focused more on the growing need to improve hardware and software. Both are growing in importance, increasing from about 25% of vehicle value to roughly 50% in less than three decades.

"The on-board value is shifting," said Tony Coopriider, Senior Technical Leader for Ford Motor Co. "Twenty-five years ago, 75% of the vehicle value was mechanical, 22% was electronics and there was a sliver of software. Software has grown to 18%, electronics is now about a third and about half is mechanical parts."

He noted that headlights have gone from a simple relay control for on-off to a glare-free high beam lamp that uses nine electronic modules to change from high to low beams when a vehicle is approaching. Coopriider also mentioned that radio head units typically run about half the lines of code in a vehicle.

That's prompting development teams to figure out ways to reuse software

throughout the vehicle. In infotainment, reuse is being augmented by utilizing open-source software. A growing number of suppliers are using it for low-level aspects of radio head unit design.

"We're looking at open source to try and control cost and drive out bugs," Coopriider said.

Moving to multi-domain controllers

While this trend is gaining steam in infotainment, it's not likely to move into mission-critical areas like powertrain and advanced driver assistance (ADAS). In these areas, developers typically focus on creating their own high reliability programs so they know exactly what every line of code does.

"Open-source software is being used primarily in infotainment systems," said Scott Morrison, Advanced Electrical Architecture Manager at General Motors. "We're trying to limit use cases so it does not spill over into high level security and safety areas."

Regardless of the operating environment, strategists are looking for ways to simplify both hardware and software. Scalability and integration were two of the panelists' watchwords. Many predicted that the number of electronic control units per vehicle will level out or decline.

"We need to consolidate what we've distributed, we want to reduce the number of controllers in a car," said Michael Groene, Director of Global Software Engineering at Delphi Automotive. "The benefit will be that we'll have multi-domain controllers. To bring functionality into one spot reduces complexity, though bringing higher density has

thermal challenges."

As vehicle electronics get more complicated, companies throughout the industry are working on ways to manage production. Both software and hardware are now being designed to simplify development and deployment as well as increase speed.

"Scalable software platforms reduce complexity," Groene said.

"Communications within the chip are faster than going over signal lines."

Rethinking supplier relations

It isn't just the growing reliance in on-board electronics that's changing design strategies. Connectivity makes it possible to do some tasks in the cloud, adding another level of complexity. That's prompting many companies to rethink the way they work with suppliers.

"There's a trend to move from on-board processing to off-board processing," Coopriider said. "That has implications for software, which now enables 90% of new features. It will change collaboration and suppliers' ownership will also change."

The challenges of autonomous driving and cybersecurity intensify the difficulties that come with automotive's reliability and safety requirements. That's prompting a focus on expanding global teams to leverage many different knowledge bases.

"Tier 1s, OEMs and Tier 2s all need to come together to overcome complexity," Groene said. "As we go to autonomy and add layers of security, we'll need to simulate more and automate our processes more. Nobody sits in one spot, everything is distributed in worldwide organizations. We have to bring them together."

OEMs are also looking for ways to tighten the links with their partners. Each of these arrangements will have to be considered individually based on the ways that these suppliers address intellectual property ownership, among other topics.

"How we want to insert our IP will impact how we choose our partners," GM's Morrison said. "Different Tier 1 and Tier 2 suppliers will insert themselves in different places."

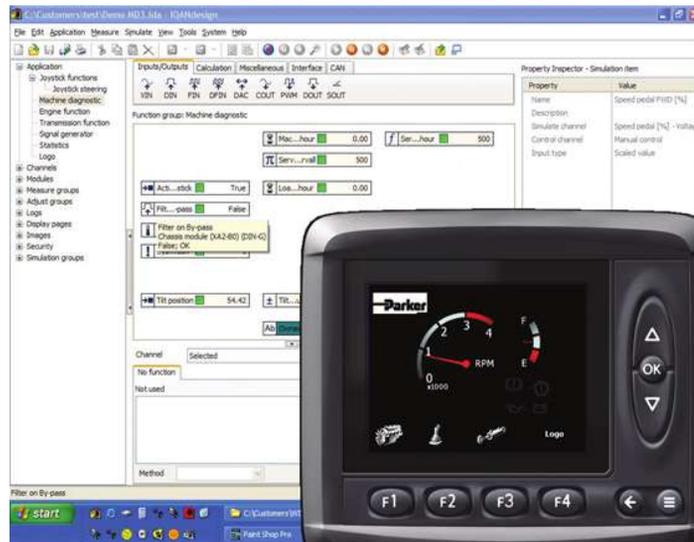
Terry Costlow

OFF-HIGHWAY ELECTRONICS

Software's role continues to expand

Software has become a central factor in many new vehicle features and functions, forcing hydraulic system developers to employ a range of technologies to meet ongoing demands for more functionality. Apps and open source programming are seeing increased interest as hydraulic engineering teams work more closely with OEMs.

Design teams challenged to add features, reduce emissions, and cut fuel consumption are relying more heavily on programming and improved communications, leveraging networks so engines and hydraulic systems work more closely together. Enhanced networking lets programs work more closely together to improve efficiency.



Engines and hydraulic systems can be matched to maximize efficiency. (Parker)

Software everywhere

The soaring volume of software has driven a shift in the makeup of design teams that create electronic systems. As in other fields, the number of programmers often exceeds the number of hardware engineers. In vehicles, the number of smart modules and the software that drives them has exploded in recent years.

"In typical off-highway applications, we estimate that the volume of software on average is three to five times what it was five years ago," said Giulio Ornella,

Off-Highway Advanced Engineering Manager at **Dana Holding Corp.**, which makes a hydraulic hybrid system.

Software must be considered from the initial concept phase through operations in the field. That's prompting more strategies to add apps to their toolkits. Most technicians will carry smart phones or tablets into the field.

Manufacturers can leverage them to make life simpler for field service personnel who currently carry several dedicated diagnostic devices. For example, **Parker Hannifin** offers an app that lets

service technicians walk up to the machine and easily hook a smart device up to Parker systems.

"To help reduce cost and reduce the time a service technician takes to hook into and diagnose a machine, Parker is releasing a new Bluetooth interface for our IQAN platform," said Kirk Lola, Business Development Manager at Parker's Electronic Controls Division. "Parker is also releasing an app for smart devices. This helps make the service technician more productive by decreasing the amount of time it takes to perform diagnostics or adjustments as well as decreasing the number of adapter cables and specialized diagnostic tools they need to carry."

As programmers race to write more code, some are exploring open source offerings.

"Some open source software is used in the development chain, including subversion and a bug tracking system," Ornella said. "We are currently evaluating other open source tools for computational fluid dynamics and scripting, including data post-processing and analysis."

Regardless of the type of software or where it is deployed, it must meet stringent reliability requirements. At a remote mining or agricultural site, a glitch or malfunction can devastate schedules and profit potentials. That's forcing companies to employ strict processes for safety and reliability.

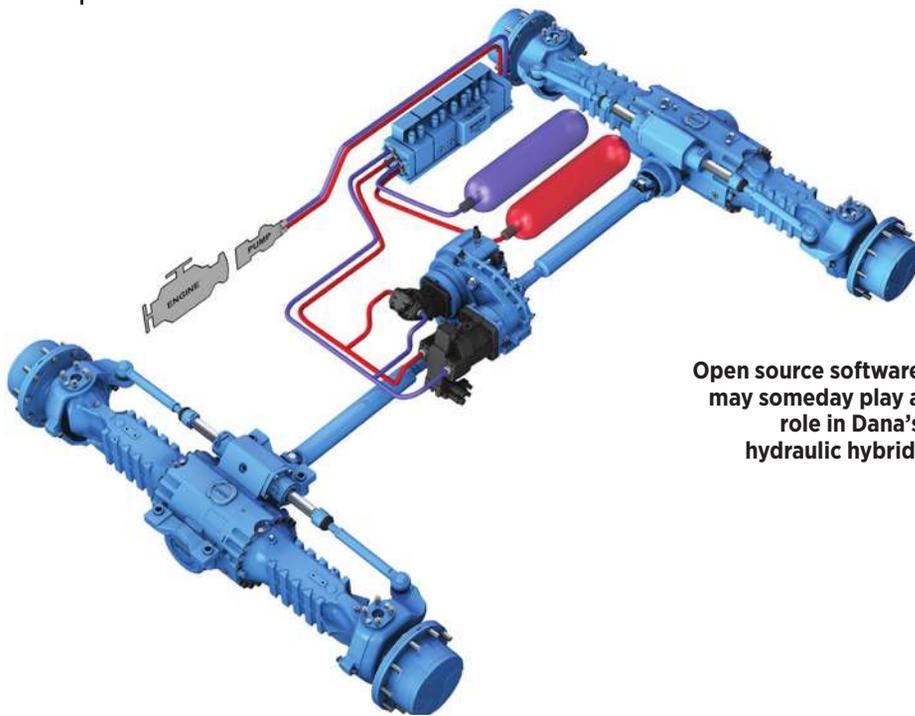
"There are processes mandated by safety standards such as ISO 26262 that



Software that coordinates functions helps Dana's hydraulic hybrid technology provide substantial fuel savings.

TECHNOLOGY

Report



Open source software may someday play a role in Dana's hydraulic hybrid.

Apps can help technicians troubleshoot Parker hardware.



provide a method for managing the necessary verification and validation processes," said Jace Allen, Lead Technical Specialist for Simulation & Test Systems at dSPACE Inc. "Fundamentally, the validation and verification done with HIL [hardware-in-the-loop] systems and virtual validation tools provide a means to test beyond the limits of safety and for very extreme conditions."

Lots of links

The explosion in software is driven in part by the shift to smart devices. It's become cost effective to embed microcontrollers in all sorts of products like valves and pumps. That's increasing network activity.

"In commercial on- and off-highway vehicles, there's a move to smart actuators, things like coolant pumps now have electronic controls," said Jason McConnell, Electrification & Hybrid Business Unit

Director, at IAV Automotive Engineering. "There's a trend where vehicle subsystems are becoming smart; they're connected to the electronic architecture and they're often connected to a master engine or vehicle controller."

These modules need to interact to maximize efficiency. When all the smart nodes communicate, they can provide better performance compared to isolated controllers that don't interact. One of the areas where there's been significant impact is in holistic management of the engine and hydraulic load.

"The ability to communicate the modern diesel engine ECUs and the corresponding hydraulic pumps and valves has opened up new areas to help prevent engine overloading, while still reaching towards optimum productivity of the machine," Lola said. "Better fuel consumption, lower emissions, and maybe even a smaller engine [horsepower] requirements are possible by matching the hydraulics to

the available engine load."

The focus on communications is altering the networking mix on vehicles. ISOBUS and EtherCAT are seeing use as a link between implements or trailers, letting them communicate with vehicle controls. Inside the vehicle, the long domination by CAN in the guise of SAE J1939 may be threatened as engineers clamor for more bandwidth and lower latencies.

"Ethernet is not happening yet, but it will be used," Allen said. "These buses provide a means to distribute functions across multiple ECUs/subsystems, but they also induce latencies in the system architectures and this has to be taken into account for robust system design."

Time to talk

The need for increased communications goes beyond networks and interlinked programs. OEMs and suppliers often need to work together more closely to ensure that performance is optimized.

That's especially true with something like a hydraulic hybrid. The controllers for the engine and hybrid must constantly communicate so they can efficiently adjust speeds and power levels. Manitou worked closely with Dana to employ Dana's Spicer PowerBoost on the Manitou MLT960 Eco-Booster 6-tonne telehandler over the course of 18 months.

"Through these efforts, Dana and Manitou have reduced the fuel consumption of the Manitou MLT960 Eco-Booster an average of 15% across a range of duty cycles when compared with the standard MTL960 configuration," Ornella said.

The trend to utilize model-based systems engineering (MBSE) has helped companies work more closely together. Groups like the International Council on Systems Engineering (INCOSE) develop and disseminate techniques that help interdisciplinary teams create successful systems.

"There is a lot of work being done to improve MBSE, with organizations like INCOSE, in order to enable better designs and processes for managing these systems and handling their necessary validation processes," Allen said. "OEMs can function much more effectively by sharing system model interfaces with suppliers and having suppliers provide models and tests with their deliverables."

Terry Costlow

AUTOMOTIVE INTERIORS

Harman advanced concept brings intuitive HMI to automated driving



Time for another chapter before my destination? While not a near-term driving scenario, it is a glimpse into Harman's LIVS in the Etos concept. ZF TRW developed the restraint systems and steering 'wheel' that retracts into the IP.



Rinspeed Etos interior shows design potential of the HMI.

Harman International is demonstrating an advanced connected-car platform that previews a fundamental shift in the human-machine interface of automated and autonomous vehicles. For this project Harman is collaborating with Swiss-based concept vehicle specialist Rinspeed, which developed the BMW i8-based Etos demonstrator featuring V2X (vehicle to everything) capability and incorporating the latest Microsoft driver "assistant."

The Harman platform, known as LIVS (Life-Enhancing Intelligent Vehicle Solution), is based on RoadLINK technology from NXP Semiconductors. The demonstrator shows how vehicle occupants will safely interact with the outside world, whether driving in SAE Level 2 or 3 automated mode, or in fully autonomous SAE Level 5.

Harman's aspiration is to develop an

"intelligent, intuitive system that, like an executive assistant, always reads what the boss wants, when you're in a good or bad mood, under stress, not putting that irritating 'phone call through or when you need a tea or coffee," explained Phil Eyer, President, Harman Connected Car Division.

Microsoft assistant 'learns'

To demonstrate that potential at the 2016 Geneva Salon, Eyer "drove" the author through an animation depicting a future commute in the Etos concept from home to the office.

"The key is moving from disparate technologies to more integrated ones in the overall experience," he explained. Although the car is stationary during this virtual drive, it is always "live" and connected to "the Cloud" via Harman

intelligent vehicle technologies. The first thing it does is authenticate the passenger and driver, via their mobile devices, as they approach. This in effect "personalizes" the vehicle to the occupants' individual tastes as Microsoft personal assistant "welcomes" the occupants to the car.

Sitting in the car, you're facing a pair of ultra-high-definition (4000 resolution), 21.5-in screens, "curved for the first time in a car," noted Eyer. The screens can be individually configured to the driver and passengers' preferences plus a smaller 2000-resolution center display. Both screens welcome driver and passenger whilst seamlessly integrating their home and car networks.

"Because it's connected to 'the Cloud' and exchange server with Microsoft, the car has access to all their contacts, calendar, etc., and can 'see' that the next destination is his office," Eyer explained.

As the vehicle emerges from the driveway it is already warning the driver of oncoming traffic in the blind spot: Etos is equipped with eight HD cameras to give the driver a surround view of the car, including objects in blind spots and "curb" cameras for close proximity parking either in the street or in narrow bays.

However, unlike Continental's rear-view camera system shown last year with its trio of cameras (one each side and a third in the "bee-sting" aerial mount), the Harman system depends on two backward-facing cameras with the images displayed on the screens.



Depending on driving mode, the electronic 'assistant' HMI will stream music or play videos to each side of the cockpit. If the car is in SAE Level 5 full-autonomous mode with the steering wheel retracted into the fascia, the driver can enjoy a game on the embedded X-Box One.

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Eyler admitted, however, that a third rearward facing camera could be installed and that the location of the display screens would be determined by the OEM customer.

Once en route, if the driver regularly asks the navigation system to guide him or her via a particular coffee shop, for instance, the Microsoft's personal assistant will "learn" this and the personal assistant will, in the future, pre-empt the driver using voice activation rather than waiting for a request.

Depending on the driving mode, the electronic "butler" will stream music via Harman's intelligent player that categorizes music based on its genre, such as classical, jazz, etc., or play the driver or passenger's favorite movie on their individual sides of the cockpit. If the car is in full autonomous mode with the steering wheel furled back into the fascia then the driver could enjoy a game on the embedded X-Box One.

If, however, the electronic assistant is aware of an impending conference call, for example, it will patch the call through complete with Power Point presentations.

Monitoring driver awareness

"Discounting the fully autonomous mode, we're already working with OEMs to offer Microsoft in cars by the end of this year/early 2017, some as facelifts of existing platforms," Eyler said, "whilst we're also developing with the display manufacturers to integrate them into our new generation of platforms."

Integral to the car's communication strategy is the technology's ability to determine if the driver is capable of receiving information under safety critical conditions. To this end the interior features five tracking cameras, including one that monitors the driver's iris to measure cognitive load to understand the driver's condition. There are also gaze tracking cameras measuring biometric rates, as well as mood detection to see if the driver is alert or needs prompting to rest and refresh themselves before continuing the journey.

Unlike some concepts this one studiously avoids the vexed "how" question when it comes to autonomous driving and driver/passenger safety.

Ian Adcock

AEROSPACE INTERIORS

Airbus brings four dimensions to Airspace



Able to accommodate up to 252 passengers, the A330-800neo is the shorter-fuselage version of Airbus' A330neo (new engine option) family of medium-range wide-body jetliners.



Launched in March 2016, the "Airspace by Airbus" cabin brand was developed and designed to offer "a flexible canvas as a back-drop to enhance airline customers' own brands."

As Airbus looks to launch new-engine option (neo) aircraft, it has announced it is also launching a new cabin brand it calls "Airspace by Airbus." In essence, Airbus is hoping that its Airspace will enhance the passenger experience just as the new engines will enhance the airlines' bottom line due to efficiency increases.

Culminating in what Airbus describes as "the best of [its] cabin innovation and design," Airspace offers "a flexible canvas as a back-drop to enhance the airlines' own brands." The new cabin is being touted as offering a more relaxing and functional environment for the passenger while optimizing space utilization. It will be launched with the



Airspace by Airbus cabins—which will stimulate a unique and leading passenger experience—are being designed to be more "relaxing, inspiring, beautiful, and functional."

A330neo wide-body airliner, which is inspired by the cabin of its in-service sibling, the A350 XWB.

The new cabins will encompass what Airbus describes as "four key dimensions," comfort, ambience, service, and design. Components of comfort making up that particular dimension will include larger overhead storage bins, updated spacious lavatories with antibacterial surfaces, wider seats and aisles, and unobstructed under-seat foot space.

Signature design and ambience elements that will be consistently recognizable throughout all Airspace cabins, including LED ambient mood lighting; clean, straight lines and shapes; clear surfaces; and also a unique, customizable welcome area at the main passenger boarding door.

Service features for operators include a range of new galley/lavatory options such as modular Space-Flex to maximize trolley capacity, wheelchair-accessible lavatory configurations to suit individual airline requirements, and freeing up of main deck space to allow for additional seating. Passengers will benefit from the cabin offering interactive entertainment and connectivity.

Jean L. Broge

AUTOMOTIVE INTERIORS | ELECTRONICS

Chipmakers gearing up for on-board wireless charging

Smart phones are becoming an integral part of vehicle infotainment options, but this integration is putting a strain on the phone's battery. In-vehicle wireless charging is increasingly seen as a preferred solution, and the normally-reticent auto industry is moving quickly to bring the technology to market.

"The auto industry has been an early adopter," said John Perzow, the **Wireless Power Consortium's** (WPC) Vice President of Market Development. "They've been faster than other infrastructure fields like hotels and restaurants."

Wireless charging has been around for years, but only recently has the technology started gaining acceptance. Two standards are currently seeing use in automotive applications. The WPC's Qi has strong automotive support. Many dual-technology applications include the PMA standard created by the **Power Matters Alliance**, which is now part of the **AirFuel Alliance**. Many analysts feel that the growth curve is pointing upward.

"Despite limited OEM implementation of wireless charging between 2012 and 2014, **Strategy Analytics** forecasts strong growth of 75.3% CAGR between 2014 and 2022, growing to 20.3 million units by 2022," said Mark Fitzgerald, Associate Director for Strategy Analytics' Automotive Practice. "Currently, dual-standard, AirFuel/Qi systems are the preferred solution."

Researchers at **IHS** said consumer awareness of wireless charging technology doubled in 2015, reaching 76% of consumers in the U.S., U.K. and China. Mobile phones with wireless power receivers surpassed 120 M units in 2015.

Some studies have suggested that drivers are more likely to set phones on a wireless charging platform than to plug

phones in, especially on short trips. Battery life is becoming more of an issue as drivers use features like near-field communication, Bluetooth and navigation.

Auto industry chipmakers are gearing up. **NXP Semiconductors** recently released the industry's first 15W multi-standard wireless charging solution. It supports the new 15W version of Qi, which will shorten charging times compared to the existing 5W technology, as well as the 5W PMA standard. Though no phones currently offer the 15W technology, it's expected to see implementation during vehicle lifetimes.

"By the time this goes into production in cars, there will be a proliferation of 15W devices in the field," said Denis Cabrol, NXP's Marketing and Systems Director. "This gives automakers staying power for the long term."

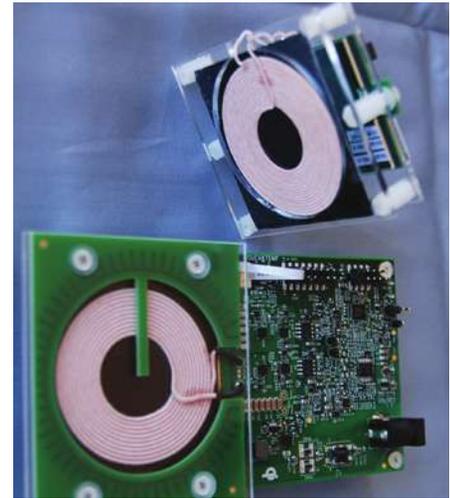
Standards battle and EMI challenges

While there's optimism surrounding wireless charging, there are also hurdles. Some cell phone providers have dropped the technology after using it, raising questions about its role. The standards battle between Qi and PMA, which are primarily inductive technologies, is exacerbated by a resonant charging standard also managed by the AirFuel Alliance.

"Multiple standards slow down progress," said Geoff Gordon, Co-chair of the AirFuel Alliance Marketing Committee. "That's why we merged [with the Alliance for Wireless Power] and brought the Rezence resonant charging technology in. We're very open to a grand alliance merger to bring all the wireless standards together."

He noted that there aren't any formal discussions to merge the two standards organizations. That means developers will have to work with two technologies, which impacts price and complexity.

"Due to the difference in the technical specification and compliance requirement, it is difficult to support multiple wireless power standards with one solution," said Pearl Cao, Systems Engineer at **Texas Instruments**. "It also may not be as cost effective, efficient, and size optimized compared to a single standard solution."



Faster wireless on-board charging will be enabled by new electronics such as NXP's 15W Qi device.

There are a few design concerns in automotive applications. Qi and PMA both operate around 100-200 MHz, so care must be taken to avoid interference with AM radios. Electromagnetic interference is a key factor in designs.

"A tightly coupled system, like the Qi magnetic induction, does not radiate much overall, as the magnetic flux is contained between the transmit and receiver coils and a ferrite screen is placed behind them," said Paolo Battezzato, Applications Engineering Manager at **STMicroelectronics**.

"However, as all systems based on switching regulators, proper design and layout are key to keep EMI below the limits."

Charging platforms housed in center consoles will also have to account for objects that move about. If metal objects like coins or keys are on the charging station, systems could over-heat, making foreign object detection a requirement. Thermal issues will also be an important factor.

"The intrinsic losses in the transmit and receive coils can be minimized up to a point," said Max Cortiana, STMicroelectronics Product Marketing Manager. "Therefore, it is critical to reduce losses in the IC and other electronic components and use proper layout techniques, to minimize power waste and assure proper heat dissipation."

Terry Costlow



Wireless simplifies charging and eliminates cables.

TECHNOLOGY Report

AUTOMOTIVE CHASSIS

Cadillac XT5's new platform cuts weight—at less cost



The 2017 XT5 departs from Cadillac's recent predilection for mixed-metal construction, but still is nearly 300 lb lighter than the SRX it replaces.

It now practically goes without saying that a newly introduced vehicle will tout a weight savings compared with not just the predecessor model, but also with competitor vehicles that may (or may not) have been developed at an earlier point in the industry's pell-mell lightweighting initiative.

So few were surprised when **GM** engineers announced during the recent media introduction for the 2017 **Cadillac XT5** that their all-new midsize crossover is a ringing 292 lb (132 kg) lighter than the SRX it replaces. No, the revelation came when they noted that XT5's new global C1 platform essentially eschews any "mixed-materials" strategy increasingly employed across the industry to achieve mass reduction on a vehicle architecture-level scale.

This seems to be a distinct materials-philosophy shift for GM's luxury unit. Compared with the aggressive lightweighting efforts for the brand's two newest cars, the 2017 CT6 full-size sedan and the mid-sized CTS, there is virtually no aluminum or other lightweight metal or composite found in the C1 structure—or anywhere on the XT5 body. Instead, GM engineers first approached this new modular crossover platform with the notion of "driving out waste" by carefully analyzing and then optimizing how the C1's various steel alloys were used—and joined—said Paul Spadafora, the CTS's Chief Engineer.

Spadafora told *Automotive Engineering* that the C1 structure

employs a range of high-strength steels and that by intricately modeling how each contributes to the overall chassis assembly, then paying particular attention to optimizing the joints not only between those steels but throughout the structure, "every ounce was looked at" and eliminated if not required.

"As different high-strength steels come together," he said, "the joints have room for optimization."

Despite gaining 2 in (51 mm) in wheelbase, an inch (25 mm) in track, and serving up 3.2 in (81 mm) more rear-seat legroom compared to the outgoing SRX, the new XT5 has nominally smaller exterior dimensions. Meanwhile, the vehicle is at minimum one full test weight class below SRX, revealed Larry Mihalko, the XT5 Vehicle Performance Manager. And, it's two classes below SRX in some trim levels.

Perhaps even more a signal of the difference a couple of years makes in today's weight-scrutinizing product-development cycles, the XT5 is a staggering 650 lb (295 kg) lighter than the like-sized **Mercedes-Benz** GLE-Class crossover and 100 lb (45 kg) lighter than **Audi's** Q5, which itself is 7 in (178 mm) shorter than the new Cadillac.

"We did it with steel," asserted Mihalko. "We were able to do it without [extensive reliance on] expensive materials." The strategy is an unmistakable departure from Cadillac's CT6 flagship, where GM's new Omega platform is a combination of aluminum and

high-strength steels and the body-in-white also is a complex multi-metal mix. In all, 64% of the 2016 CT6 is said to be aluminum. The CT6, reported *Automotive Engineering* in April 2015, is "arguably the industry's most aggressive combination of lightweight materials, forming technologies and new joining methods in a non-exotic sedan."

Prior to the CT6's launch, Cadillac took a similar path with the all-new 2014 CTS midsize sedan, where a weight-prioritizing development program cut poundage 7% compared with the previous CTS and made the car some 200 lb (95 kg) lighter than an equivalent **BMW** 5-Series.

Despite the CTS's acknowledged dynamic excellence, however, its hardline lightweighting translated to a cost that put the CTS at a disadvantage in the hyper-competitive midsize luxury sedan market. Johann DeNysschen, GM Executive Vice President and President of Cadillac, flatly admitted to journalists at the XT5 launch that the aluminum-intensive CTS "costs a lot of money to make."

Whether the experience from its newly lightened sedans had any influence on the C1 platform's "steel only" development direction is difficult for outsiders to know. But what's certain is that the C1 achieved a high degree of mass reduction with a 10% upgrade in torsional stiffness (and hit its first-order beaming-mode targets, said Mihalko) without resorting to high-cost light materials.

However, the platform is not the only source of the crossover's significant diet. Also contributing were the design of the vehicle's all-new 5-link rear suspension, which accounted for 70 lb (32 kg) of the XT5's total weight loss. Advances to the dissipative materials used for acoustic attenuation chopped another 30 lb (14 kg).

But for the C1 architecture, which will underpin a spate of different-sized future Cadillac and other GM-brand crossovers including the upcoming **GMC** Acadia, design optimization was, in effect, more important than the materials themselves.

"It all goes back to analytical tools," Mihalko claimed. "They just keep getting better."

Bill Visnic

AEROSPACE BODY

Innovative wing structure contributes to Clean Sky next-gen aircraft

GKN Aerospace announced earlier this year that it has delivered wing components as part of a major research program to test and measure the benefits of natural laminar flow (NLF) designs during trials on the wing of a flight test aircraft. The Breakthrough Laminar Aircraft Demonstrator in Europe (BLADE) project is part of the Clean Sky Smart Fixed Wing Aircraft (SFWA) program, an extensive, 50% European Union-funded, multi-partner activity aimed at lowering fuel consumption and emissions by reducing drag on next-generation.

“The SFWA BLADE program is allowing us to progress innovative technologies, concepts and capabilities with the potential to bring about a step change in aircraft fuel consumption,” said Russ Dunn, Senior Vice President, Engineering and Technology at GKN Aerospace.

GKN Aerospace has delivered the critical leading edge assemblies and upper covers that form part of the NLF wing section on the starboard wing of the **Airbus A340** flight test aircraft. These structures offer NLF levels of performance through the adoption, by GKN Aerospace, of a totally new design approach and the application of novel manufacturing technologies that deliver the ultra-high tolerances and exceptional surface finish required.

During flight tests, taking place in 2017, this wing section will be used to test the performance characteristics of NLF wing architecture, helping prove predicted economic and environmental benefits: An NLF wing is expected to reduce wing drag by 8% and improve fuel consumption by approaching 5%.

“The key challenge with designing and manufacturing an NLF wing, with the many aerodynamic benefits that promises, stems from the need to tightly control the wing surface,” said Dunn. “It is vital to eliminate features such as steps, gaps, surface roughness and waviness or fastener heads as these all lead to more traditional ‘turbulent flow’ performance levels. The GKN Aerospace team has created these integrated, co-cured composite upper covers and very high tolerance leading edge surfaces using the same structured design and development process



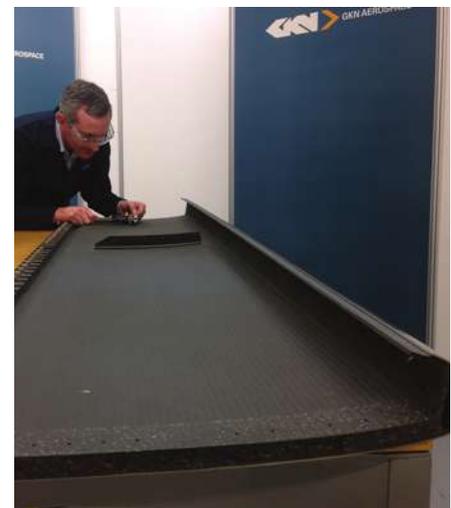
GKN Aerospace innovative wing leading edge assemblies, delivered to Airbus for the Clean Sky BLADE program.

applied in commercial aircraft programs. As a result, our first part was of very high quality and has been delivered for the flight test program.”

The ground based demonstrator (GBD) of the wing developed a couple years ago was a 4.5 m x 1 m section of flight-representative wing leading edge attached to a partial wing box assembly. The leading edge accommodated a Krueger flap in two sections, which allowed GKN engineers to investigate two very different design philosophies.

The first “baseline” section applied a monolithic composite skin to the traditional rib design seen on the majority of metallic leading edges today. The second “innovative” section applied a more radical design to address issues experienced meeting NLF tolerances with the baseline design. This section comprised a lightweight leading edge sandwich panel incorporating electro-thermal wing ice protection technology with an integrated erosion shield and fastener-free outer surface.

Additive manufacturing processes were used to create a novel support structure for the Krueger mechanism, replacing the aluminum ribs in the baseline design. This allowed the leading edge panel to be supported by just three composite ribs: a single central rib and two closing ribs. These maintain the correct leading edge aerodynamic profile over the complete range of operating



Innovative wing leading edge composite sandwich panel, produced as part of the Clean Sky smart fixed wing aircraft program, shown in its ground-based demonstrator phase.

temperatures. The innovative section had a lower component and fastener count, was significantly lighter, and had greatly improved performance predictions compared to the baseline section.

The overall project was a collaboration between three GKN Aerospace technology centres in the U.K.: a team at the U.K.’s National Composites Center, at GKN Aerospace in Luton, and at the GKN Aerospace additive manufacturing center in Bristol.

Jean L. Broge

AUTOMOTIVE BODY | MATERIALS

Nanotechnology may provide self-cleaning, energy-saving 'smart glass' for vehicles

Improving driver visibility is a major aspect of vehicle safety that is increasingly supported by stereo cameras, LiDAR, and infrared systems. But fundamental to visibility is being able to see clearly through clean glass windows, and front and rear windshields.

Now, researchers at a U.K. university have revealed a "smart" window solution for buildings that may also be applicable to vehicles. It uses nanotechnology to achieve not only self-cleaning but also delivers energy saving and anti-glare properties.

"This is the first time that a nanostructure has been combined with a thermochromic coating," said Dr. Ioannis Papakonstantinou of the Department of Electronic and Electrical Engineering, **University College London (UCL)**. "The bio-inspired nanostructure amplifies the thermochromic properties of the coating, and the net result is a self-cleaning, highly performing smart window."

As project leader of a highly specialist team, Papakonstantinou said initial applications of nanostructures could be to skyscraper windows but at present he believes that in theory there was no reason why the system could not be extrapolated to road vehicles provided

it met required safety standards and other legislation.

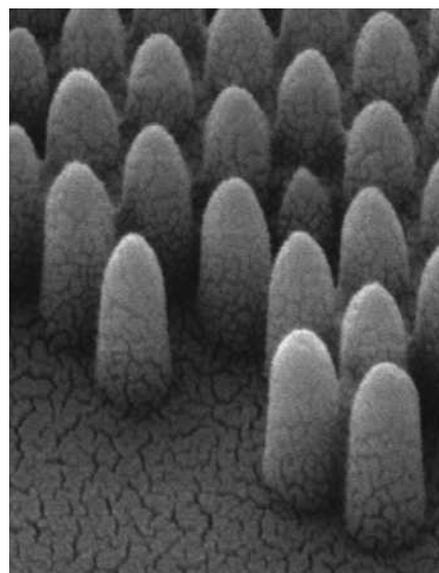
"It should, because it simply involves application of a coating of about one micron. But of course there would need to be a test program to establish—for example, how quickly water droplets would flow down automotive glass, particularly the windshield."

The research work at UCL is being supported by the U.K.'s **Engineering and Physical Sciences Research Council**, and prototype examples of the technology are said to confirm that the three key benefits can be delivered.

The self-cleaning application sees rain hitting a glass surface to form spherical droplets that roll easily across that surface carrying away dust, dirt, and any other contaminants. Explained Papakonstantinou: "This is due to the pencil-like, conical design of nanostructures engraved onto the glass, trapping air and ensuring that only a tiny amount of water comes into contact with the surface."

Regular glass typically sees raindrops clinging to the surface before sliding down, leaving marks.

To achieve energy saving, a glass surface is coated with a 5- to 10-nm (0.2- to



A scanning electron microscope image of the nanostructures engraved onto glass. Controlling the surface morphology at the nanoscale allows high precision tailoring of the glass's interaction with liquids and light.

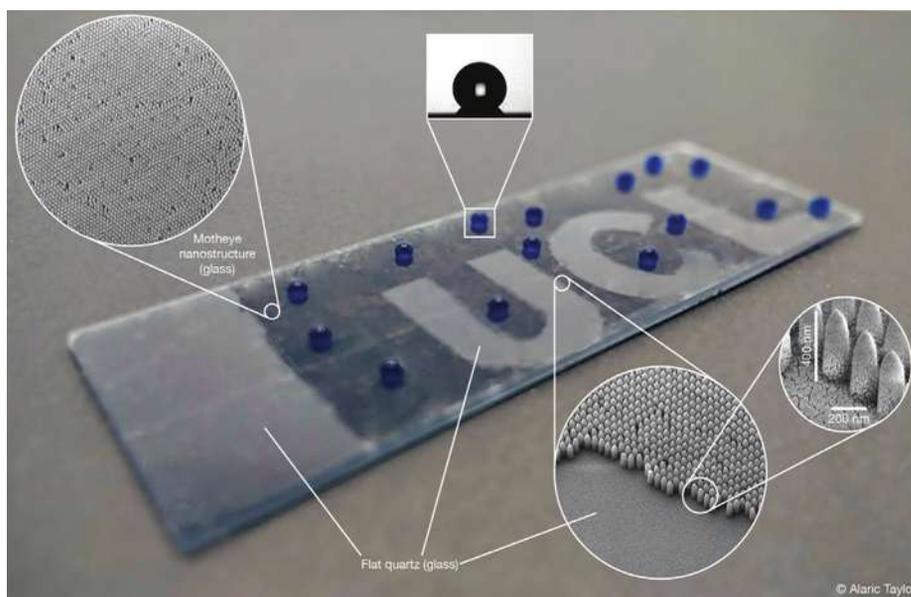
0.4- μm) film of vanadium dioxide (a cheap and abundant material), which prevents heat loss or, in hot climates, prevents solar IR entering the vehicle.

"The design of the nanostructures also gives the windows the same anti-reflective properties found in the eyes of moths and other creatures to hide them from predators!" noted Papakonstantinou. "It cuts the amount of light reflected internally in a room to less than 5% compared to 20-30% achieved by other prototype vanadium-dioxide-coated energy saving windows."

He stressed that the UCL findings are the result of a research project and that the next big step would be to scale-up the nano manufacturing techniques and the vanadium-dioxide coating process used to create the prototypes. For this purpose, Papakonstantinou has secured a €1.8M grant from the **European Research Council**.

The UCL team also includes Prof. Ivan Parkin of the university's Department of Chemistry, and researcher Alaric Taylor of the Department of Electronic and Electrical Engineering.

Stuart Birch



A prototype of UCL's "smart glass" solution. The dark areas indicate nanostructures that repel water, forcing it to form near-spherical droplets and prevent it from wetting the glass. The UCL logo is of untreated glass and demonstrates significantly more reflection than the surrounding area.

AEROSPACE, AUTOMOTIVE, OFF-HIGHWAY MATERIALS

Biomimetics: nature leads the way on design

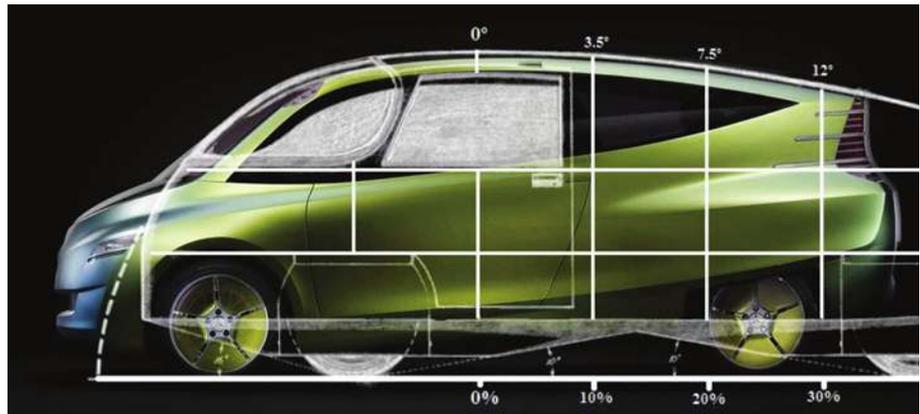
That bird flight inspired Leonardo da Vinci to conceptualize “flying machines,” only to be developed centuries later by the Wright brothers by observing pigeons in flight, is quite well known. Such imitation of the models, systems, and elements of nature for the purpose of solving complex problems, otherwise known as biomimetics or biomimicry, is not new. Mother Nature is a great engineer that over the years has fascinated engineers and scientists alike, who have borrowed and applied its time-tested patterns and strategies. Technological advancements and continuous endeavors to push the limits of engineering have led to transformational innovations, as can be seen in some of the recent trends to catch up with nature’s best assets.

Velcro is perhaps the best known and commercially successful example of a nature-inspired design. After a hunting trip in the Alps in 1941, Swiss engineer Mestral’s socks and dog were covered in burdock burrs. Intrigued by it, Mestral studied them under a microscope to understand the simple system of interlocking hooks and spent the next few years developing Velcro. Such mimicking of nature’s precise and efficient shapes, structures, and geometries is referred to as the basic level of biomimicry, by American biologist Janine Benyus.

Transportation applications

In aerospace application, examples of nature-inspired designs to create efficient and environment-friendly products are aplenty. Various types of craft use radar and sonar navigation technology inspired by the echolocation abilities of bats and dolphins. The wingtip of eagles and other birds have inspired the design of airplanes with adjustable wingtip mechanisms that can change shape depending on speed and length of a flight in order to improve efficiency.

Aviation engineers are currently testing ways to create bird-like maneuvers and adjustments for the aircraft to land smoothly and accurately, which may potentially eliminate the need for runways or brakes in the future. In yet another triumph of biomimicry, NASA



Engineers at Mercedes-Benz sought inspiration from boxfish for the design of the Bionic Concept car introduced in 2005.

has successfully demonstrated improvements in aerodynamics over a range of speeds due to morphed airplane wings, which can change shape much like birds and covered with a segmented outer skin like the scales of a fish. Retractable brush-like fringe to mimic the owls’ trailing feathers and velvety coating on aircraft landing gear are being developed for silent flight.

It is believed that a shark’s skin composed of jagged scales covered with longitudinal ridges provides it with just the right kind of roughness to easily slice through the water. Developments are under way to create a synthetic replica of shark-skin coating that can help to improve aerodynamic characteristics of airplanes and reduce fuel consumption significantly. Nanotechnologists have tried to replicate surface properties like micro texture (wavy surface protrusions) of lotus leaf to achieve similar ultrahydrophobia or super-hydrophobic properties. By using fluorochemical or silicone treatments on structured surfaces or with compositions containing micro-scale particulates, they have been able to develop treatments, coatings, paints, fabrics, etc. that can stay dry and clean by itself, referred to as the “lotus leaf” effect.

Biomimetics has led to material level developments of bionic structures that

mimic the bone structure of birds. Such structures provide a fuselage with the strength it needs while reducing overall aircraft weight and fuel burn, allowing additional space wherever needed. The cabin electrical system can be compared to the human brain, with a network of intelligence pulsating through the cabin. This network will be absorbed into the structural materials, making hundreds of kilometers of cables and wires found in today’s aircraft a thing of the past.

Amongst automotive applications, engineers at Mercedes-Benz sought inspiration from boxfish to develop a rather unusual design form but one of the most efficient shapes with one of the lowest coefficients of drag ever tested. Similarly, the Shinkansen bullet train in Japan was designed based on the kingfisher. The train travelling at 200 mph (320 km/h) made a thunderous noise especially while emerging from tunnels due to air pressure changes. The bill of the kingfisher, which enabled the bird to dive at high speed from one fluid (air) to another denser medium (water) with barely a splash, inspired the design of its front end. This not only reduced the noise level significantly, but also contributed to 15% less electricity consumption while traveling 10% faster.

TECHNOLOGY Report



The Shinkansen bullet train in Japan was designed based on the kingfisher, resulting in reduced noise and electricity consumption while traveling faster.

Material developments

Some of the recent developments in the area of adhesives, fabrics, etc. have wider application areas across different industries beyond automotive and aerospace. A popular alternative to adhesive has been developed by **Manchester University** scientists studying the feet of geckos. This super-adhesive is so powerful that an index-card sized piece can hold 700 lb (320 kg) on a smooth surface, such as glass, yet can be easily released, and leaves no residue. Similarly, scientists are finding ways to produce stronger fabrics like the webs of spiders that are stronger than steel.

Benyus suggests the imitation of natural processes and biochemical “recipes” as the second level of biomimicry. The owl feather self-assembles at body temperature without toxins or high pressures, by way of nature’s chemistry. The unfurling field of green chemistry attempts to mimic these benign recipes. The most sophisticated application is to mimic ecosystems, where organizations behave like organisms and create symbiotic relationships with each other—e.g., a chemist at **Cornell University** has developed biodegradable plastic using waste CO₂ from a

cement factory and limonene (a major component in the oil extracted from citrus rind). This is referred to as the third level of biomimicry.

Growing successes only reaffirm that nature is the greatest invention-machine in the universe, how its organisms can be regarded as mentors, and its processes to be deemed masterful. With time, engineers and scientists are increasingly looking for clues from the history of evolution by natural selection, to find answers to their most complex problems. In spite of biomimicry inspiring innovation in myriad ways, researchers believe that we have so far only scratched the surface of what’s possible. Continuing this trend will only enable organizations to marry industrial problems with natural sustainable solutions.



Satya Swaroop Panda and Chana Kesava Reddy of the Global Engineering Centre, Interiors, UTAS India, wrote this article for *Mobility Engineering*.

AUTOMOTIVE MATERIALS

DSD, Solvay ‘sink their teeth’ into plastic transmission advances

For the automotive industry, plastics have long been a weight-saving material of choice, with a wide range of high-volume applications from body panels to interiors and underhood components—but transmission housings and gears are not among them.

Now that may change. Two European companies are collaborating in a study to achieve solutions that could herald a much wider role for plastic composites across transmission applications, and they are using electric vehicle (EV) research to help refine the technology.

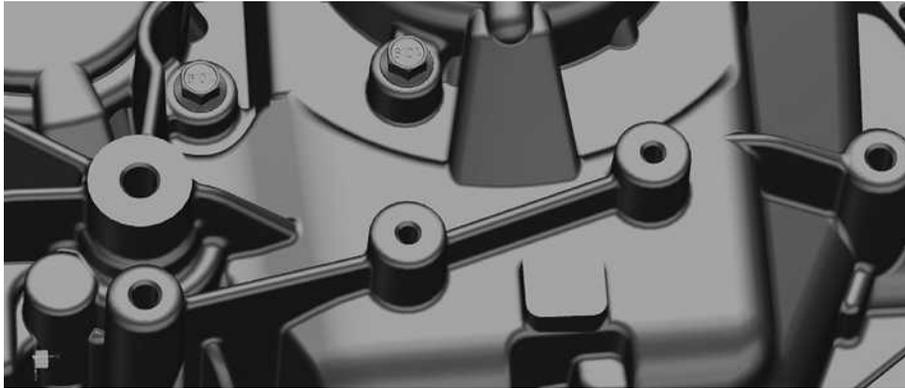
The companies are U.K.-based **Drive System Design** (DSD), an engineering consultancy specializing in transmission design, development, and control, and Brussels-headquartered **Solvay**, an international chemicals group operating in sectors that include automotive, aerospace, energy, and the environment.

Based on their joint initiative to create a plastic transmission housing to improve NVH characteristics of a future pure EV, both companies are also exploring the possibility of using the material to improve the efficiency of meshing gears via tooth. In terms of noise, that would rule out using metals.

DSD Managing Director Mark Findlay explained: “There is an immediate weight saving from substituting plastic materials for conventional metal castings, but equally important is the potential for



Mark Findlay, Managing Director of engineering consultancy DSD, believes there are significant opportunities for plastic as an alternative material for transmissions.



DSD and Solvay are refining designs using composite material that would be suitable for transmission applications such as this case.



Solvay composite material was used to create these sprockets.

improved efficiency. The inherent damping provided by polymeric materials permits the use of much more efficient gears, such as reduced helix angles or spur gears, that would have unacceptable noise characteristics in a conventional casing. By using shorter teeth, typical tooth profiles for higher efficiency would have reduced sliding and increased rolling.”

He believes there is potential for shafts, casings, and hydraulic valve bodies to be made from plastic (suitably reinforced where appropriate), and states that full implementation could produce savings of up to 45% in casing weight for a typical passenger car transmission. With an NVH “skin” added, the savings would still reach 25%. A reduction in transmission losses would be “up to 0.5% per gear mesh.”

There is nothing new in wanting to extrapolate plastic’s roles into fundamental powertrain technology, but wanting and achieving are not the same things.

In the late 1960s, **General Motors** considered composite gearboxes and created prototypes. **Formula One** and aerospace industries have also embraced R&D programs that looked at possibilities.

In the 1980s, when such advances

were seriously mooted, contemporary composites’ technology could not deliver radical powertrain application solutions such as casings and gear teeth for high-volume requirements; now it may be able to.

Findlay is pragmatic about these possible developments and stresses that it is in the premium EV category that the technology is likely to find its first application to help counter NVH: “The low cabin noise levels in a vehicle without an IC engine expose any NVH issues arising from the driveline, making the inherent damping of a plastic housing advantageous.”

Temperatures encountered in an EV are lower than an IC engine powertrain, so are more compatible with lower cost polymer temperature limits of around 120°C (248°F). An interesting point made by Findlay is that current production EV production volumes are hugely lower than those of conventional vehicles, making it easier for manufacturing technology eventually to migrate from prototype quantities to series production levels.

There are challenges, he said: “New and unfamiliar materials bring pitfalls for the unwary because of the subtleties of the mechanical properties, which can



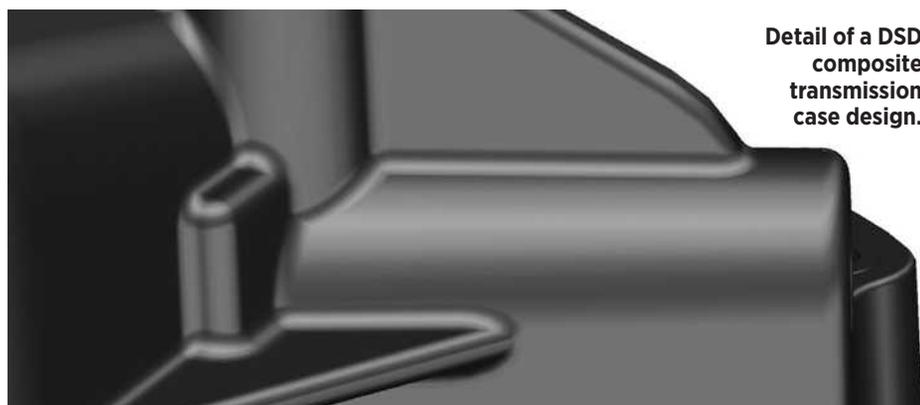
Mark Wright and his company Solvay are working with DSD on the use of composite materials for powertrain applications.

change by up to 50% over the operating temperature range due to non-linear behavior. Polymers soften above their glass transition temperature, which can significantly affect mechanical properties; even the moisture absorption of polymers can influence properties. It’s always good practice to work with a material supplier from the earliest stage of design but, when the material properties are as different as polymers and metals, it is absolutely essential.”

That is why DSD and Solvay are busy cooperating to meld their individual specialist capabilities.

For the plastic transmission study, low-cost composite technology is being incorporated from the outset to combine structural capability with volume-feasible manufacturing costs. Including the typical industry allowance for weight reduction at \$10/kg saved, DSD believes composite transmission casings can be engineered to be competitive in price with existing aluminum products.

Solvay states that durability prediction has been greatly enhanced by effective finite element (FE) analysis, backed by proven data on mechanical properties and appreciation of the influence of parameters such as mold flow characteristics and fiber orientation (for composites). The recycling of plastic-only



Detail of a DSD composite transmission case design.

TECHNOLOGY Report

components is regarded as being straightforward, and research into composite recycling is ongoing; an issue that is common to all material manufacturers. All this is germane to the possible drive-train developments.

Said Findlay: "Our preferred approach for a transmission casing is composite construction involving overmolding a polymer around a structural frame to provide a continuous barrier against any ingress of oil, which could otherwise infiltrate and weaken the bond between the inserts and the polymer."

DSD and Solvay are currently discussing with vehicle manufacturers the areas within transmission and driveline systems that offer the best potential for material substitution in the future. Currently, the technology is in the development phase to optimize and prepare the most suitable materials and processes in a near-production-ready state.

DSD and Solvay anticipate a five- to 10-year timescale before the first applications come to market.

Solvay's Global Automotive Marketing Manager, Mark Wright, underlines that it is important to approach potential customers with a range of alternative ideas: "Each customer has individual priorities, whether for weight reduction, NVH improvement, or increased efficiency. We have to reflect that by presenting the most appropriate options for their particular case."

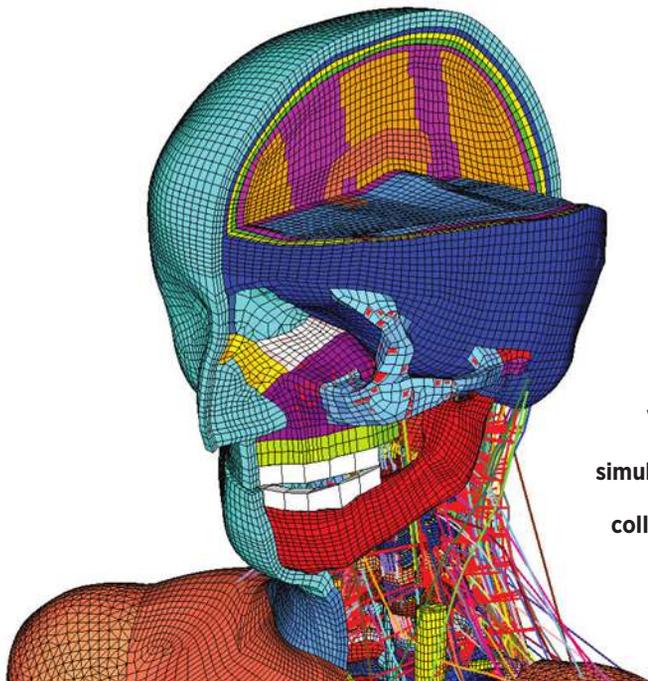
He explained that Solvay has taken part in "a number" of high-profile projects to demonstrate the potential of its materials: "We supply the Solar Impulse—an experimental zero-carbon, solar-powered aircraft attempting to fly around the world—with 15 different Solvay products, and also support the Polimotor 2 race engine program by providing several different thermoplastic materials."

Polimotor 2 is composites intensive and will use Solvay's advanced polymer technology to develop up to 10 engine parts, including a water pump, oil pump, water inlet/outlet, throttle body, fuel rail, and other high-performance components. Solvay materials targeted for use encompass Amodel polyphthalamide (PPA), AvaSpire polyaryletherketone (PAEK), Radel polyphenylsulfone (PPSU), Ryton polyphenylene sulfide (PPS), Torlon polyamide-imide (PAI), and Tecnoflon VPL fluoroelastomers.

Stuart Birch

AUTOMOTIVE SIMULATION

Digital dummies in virtual collisions augment traditional crash tests



Wayne State University's CHARM 10 human body simulation system models the body's behavior in auto collisions down to the organ and tissue level.

A car crash takes half a blink of an eye. Detailed knowledge of the crucial split-second when the crash impact energy flashes through a vehicle's body and then onto the occupants' bodies is critical to building safer cars.

For decades at automakers' test tracks such as GM's Milford Proving Ground in Michigan, crash test dummies have endured repeated near ballistic collisions to provide that key data to safety and vehicle engineers. Through the years, the familiar bull's-eyed manikins of steel, rubber, vinyl, and foam have grown increasingly sophisticated, said Jack Jensen, Engineering Group Manager at the lab and GM Technical Fellow.

Fitted with the latest instrumentation, crash dummies have essentially become flight-data recorders, black boxes in human form, as the sensors and transducers are now self-contained and wireless, whereas previous dummies needed cables that could restrain free movement, Jensen said. "The new dummies can have 140 channels of data delivering at a rate around 10 samples a millisecond, which quickly fills huge files."

Humanetics Innovative Solution of Plymouth, Michigan, U.S., is the leading supplier of anthropomorphic test devices, or ATDs.

ATDs are fitted with accelerometers, load cells, angular rate sensors, and displacement gauges, which "gives you so many *g*'s, so many Newtons of load, millimeters of deflection," he explained. The deflection numbers, for instance, "let us measure the compression of the chest cavity or distance between the sternum and spine." These metrics help define injury criteria for predicting the statistical risks of injuries.

"We have about 190 to 200 crash-test dummies in a wide range of sizes, shapes, and ages," Jensen continued. Dummies are not cheap; they can go for \$125,000, even a half-million dollars a copy.

Digital dummies

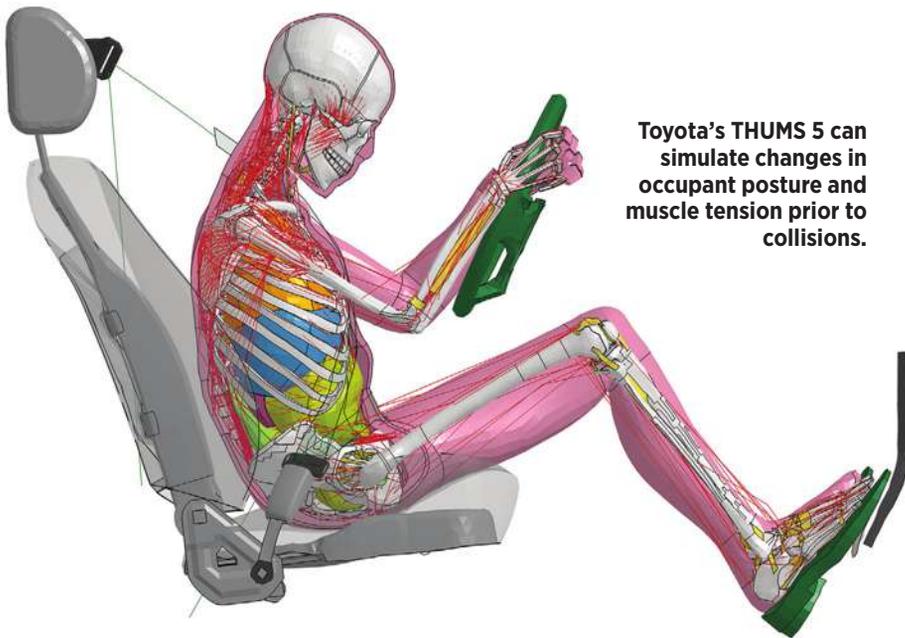
More and more at the automakers nowadays, digital crash test dummies made of zeroes and ones are taking the big hits in virtual vehicles, he said. The simulated crash tests using computer-aided design (CAD) and engineering (CAE) systems to do finite element modeling and analysis allow GM engineers to learn earlier in the design process, before the hardware is available and built, and also optimize the performance across a broad range of test conditions.



Ashley Weaver, a researcher at Wake Forest University, and her colleagues use THUMS simulation to analyze car crashes in detail to study how to improve safety systems. (Photo courtesy of Wake Forest University Center for Injury Biomechanics.)



A crash test engineer adjusts the position of a crash test dummy at the Anthropomorphic Test Lab at GM's Milford Proving Ground. (Photo by Chris Guddeck for GM)



Toyota's THUMS 5 can simulate changes in occupant posture and muscle tension prior to collisions.

"We still do a lot of physical crash tests here at Milford," Jensen noted. The collisions are used to validate the models, confirm performance predictions, or when system capabilities are still evolving. Real dummies will be needed because simulations fail to capture everything that happens in a crash test or that an ATD can measure, so GM uses both physical and virtual dummies. They also use the software to model the behavior of physical dummies themselves because governments define safety regulations according to real-world crash tests.

"We might run a physical crash test to get a baseline regarding how the vehicle or safety system performs," he said. "Then maybe we'd implement a series of incremental improvements using say, 20 computer simulations, and finally, build the new optimized vehicle or system for testing. But even though CAE allows us to reduce the number of physical collisions for analyzing a given engineering condition, the constant search for new hazardous conditions to consider means we're doing more vehicle crashes than ever before."

Virtual drivers and passengers

In 2003, Toyota introduced for public use the Total Human Model for Safety (THUMS) virtual human model software. THUMS, which was co-developed with Toyota Motor Central R&D Labs, is the most popular vehicle passenger safety simulation, said Jason Hallman, a vehicle safety engineer and biomedical engineer. The software today has 150 users and licensees including automakers, seat suppliers, research transport safety centers, and academic institutions.

"Right now we're on THUMS v. 4, which is a finite-element physical framework in



GM engineers in Warren, MI, discuss CAE simulations that accurately depict how the structure and components of the 2015 Trax would react in a crash.

TECHNOLOGY Report

which the body's hard and soft tissues—the bones, organs, muscles, ligaments, tendons—have been simulated in detail,” Hallman said. “The result is a model with 2 million elements.”

One of the academic institutions that uses THUMS 4 is a team of modelers at **Wake Forest University**: “We’ve reconstructed about eleven motor vehicle crashes—both frontal and side impacts—that caused acute injuries,” said Ashley Weaver, Assistant Professor of Biomedical Engineering. “By simulating real-world crashes, we can study the effect of vehicle design parameters, safety features, and occupant factors to improve safety.”

The THUMS system models three body categories: a large male, a medium man, and small woman, whereas two other classifications—young child and elderly female—are simulated by Collaborative Human Advanced Research Models v. 10 (CHARM 10), said Steve Ham, Toyota Senior Principal Engineer, who focuses on biomechanics.

“The technical background behind CHARM 10 and THUMS are substantially the same,” Ham said. “But you need specific models to represent children and the aged because their body geometries and the materials properties of their tissues are not the same as those average adults.” For a 10-year-old, the head-to-body ratios are different and the pelvic bone still has a weakness, a gap in it, he said. A 70-year-old woman typically has osteoporosis.

More specialized body types are needed, but because it can take several years to build one, Hallman and a team at the **University of Michigan** are developing a way to produce them quicker. Using body data from population studies, they mathematically morph existing finite-element models of skeletons and whole bodies across multiple body sizes and shapes. (See <http://papers.sae.org/2016-01-1491/>)

The greater scalability of the details would let engineers better fine-tune airbags, seatbelts, and passive safety systems to a wider range of bodies, Ham noted. Likewise, THUMS 5, which is being readied for release, will help evaluation of safety equipment by enabling more detailed analyses of post-crash injuries because it better simulates the body attitude and muscular state of a vehicle occupant when relaxed or braced for impact.

Steven Ashley

OFF-HIGHWAY MANUFACTURING

Caterpillar eyes 3D printing for production parts

This past November **Caterpillar** opened its new Additive Manufacturing (AM) Factory at its Tech Center in Mossville, Illinois, U.S., to consolidate and expand its 3D printing activities and to better serve its internal and external customers by advancing the “disruptive” technology. The AM Factory currently houses many state-of-the-art machines, with plans to expand. These span the gamut of technologies including DMLS (direct metal laser sintering), SLS (selective laser sintering), FDM (fused deposition modeling), SLA (stereo lithography), and material jetting technology. Additionally, located off-site but nearby at the company’s foundry is a binderjet sand printer. Twelve people work in the Additive Manufacturing group, including engineer Brittany Hancock. She recently gave select media a tour of the new Mossville facility and discussed Caterpillar’s current and future plans regarding the use of 3D printing technology.

Where was Caterpillar’s 3D printing done before this new facility?

There were a couple of machines (SLA and FDM) at the Tech Center in the Rapid Prototyping Lab. In the other building across the street were a FDM and material jetting machine. Last November when the new space was completed here at the

Tech Center, everything was combined and some new machines added.

SLA machines are the original rapid prototyping technology, invented in the late '80s. Cat has used this technology since the early '90s. We’ve used rapid prototyping for years to produce prototypes, fit-up parts, and scale models. Now we’re investigating the possibility of using additive for production parts.

What are some things you’re currently working on here?

Currently on the machines, there are parts for a new cab interior for a fit-up build at our proving grounds. The engineers want to get a feel for the operator environment. There also are some scale models and various parts for a new concept one of our design engineers is working on.

What’s the advantage of doing it this way vs. a build at a machine shop?

Quicker, and sometimes cheaper, especially if you need one part. Also with 3D printing you can print designs that are not possible any other way. These are the exciting projects and Cat is working on a couple. The interior cab parts we are currently printing are a good example. These are 3 ft long and about 6 inches wide, and to make both of them is going to take



One function of the Additive Manufacturing group is to educate Caterpillar engineers around the world about 3D printing and its possibilities, said AM engineer Brittany Hancock.

about 75 to 80 hours. This may seem like a long time, however the correct material was in the machine, the schedule opened up, and we were able to print quicker than determining how to machine the part out of stock material.

Another good example of the advantage of 3D printing is the track links we printed last year for the manufacturing factory. Cat had a new design about a year ago and the casting wasn't going to be in for about 10 weeks. In the meantime, the factory had programming for machining processes, measuring equipment, and finishing operations that needed to be completed for the track link. The AM Factory printed 36 plastic track links for them and the manufacturing engineers were able to complete this work before the first cast track link ever came into the factory. Printing saved us time, money, and enabled them to troubleshoot the programs.

Beyond prototyping, do you have any production parts yet?

Yes, some of the parts we have for production are back-up rings, which keep a seal in place on a hydraulic cylinder, and a dealer service tool for O-ring installation. These parts are available through our parts-ordering system and printed on demand.

Another part we have printed for a customer is a shade bracket for an excavator. The shade brackets are generally injection-molded. However, the supplier for the brackets had shut down and the tool was gone. The customer needed one set; therefore, the AM Factory printed the set.

Cat is in the process of looking at other parts for production and completing validation work. When choosing a part for production, you want to make a smart choice and determine that you've picked out the right part for the right reasons.

What types of other parts are you looking at for production?

Since they're not validated yet, I can't say which ones.

What types of materials do you work with in this lab?

There are plastic and metal materials. The SLA and material jetting technologies print UV-cure plastics. The FDM printers print plastic grades that are generally used for injection-molded plastics—ABS, nylon, ULTEM polyetherimide (PEI) [from SABIC], polycarbonate, and



Sprocket designed for additive manufacturing shows the detail possible with 3D printing.

ASA (acrylonitrile styrene acrylate).

Currently our metal printer is running 17-4 stainless steel. Once we are good at printing this material we will try another material. Metal printers have the ability to run aluminum, stainless steel, maraging steel, and cobalt-chrome. This machine was a new addition and just came online earlier this year.

What determines if you use metal or plastic for a part?

The end use of the part determines material type. If a design engineer has an NPI (New Part Introduction) part that they are looking for a mockup of or a simple fit-up part to see how it interacts with other parts, generally we recommend printing that type of part from plastic. Even some production parts we'll make out of plastic, because that is what the design requires. It's about getting the right material for the job and that's part of our job here at the AM Factory. People come to our Additive engineers with what they want and the knowledge of what the end use for the part will be, then we help them determine what printing process, material, and post processing is needed to get the right part for the job.

What are some parts that you would agree metal is best for?

Parts that are going to be exposed to higher temperatures or chemicals that the current plastics for printing cannot withstand or parts with high structural loads. For example, prototype engine parts like rocker arm and fuel swirlers could be direct metal printed.

Low volume or prototype castings are also good candidates for printing because the mold can be printed from

a sand printer then the part poured from production-intent metal. This provides a good way to get a metal part without printing the part, but the tooling to produce the part.

How busy are you? How long would I have to wait if I have a request?

Currently the AM Factory is fairly busy. There is a schedule for all our printers. We generally tell people two weeks from the time they approve the quote to have a part in hand. Variables that effect the timing are: what material is being requested and when is that material scheduled to run in the printer, what type of finish is required, are the files provided ready to be printed or is there pre-work involved to prep the files for printing (there is almost always pre-work required), and what post work is needed (paint, sealing, machining, etc.).

What is Caterpillar doing to expand 3D printing organization-wide?

Another thing the AM group is trying to do is educate engineers about 3D printing. With locations all over the world and thousands of engineers, that can be a difficult task. One program that has worked well for us is the Nomadic Printer Program. This program loans a small FDM printer to a group for about 6 months. This gets engineers and others outside the AM group exposure to 3D printing. This program has been in place for about a year and a half with a very successful outcome. Our manufacturing facilities have used these "nomadic printers" to create customized tooling for their facilities that saves them time, money, and makes their job safer.

Ryan Gehm

Base-engine value engineering for higher fuel efficiency and enhanced performance

Introduction

To sustain a market-leadership position, one has to continuously improve their product and services so that customer expectations are met and business profitability is maintained. Value engineering is one approach to achieve these two objectives simultaneously. Enhancing the value of running products always is a challenge, as there is limited scope and flexibility to modify the current design and processes.

This study reveals approaches to upgrade the base engine of the Maruti Alto and Alto 800 launched in October 2012. Improvement points were studied based on the business requirement, market competition, and legislative requirements. Based on functional improvement points, all the design parameters were studied and finalized. The finalized design parameters then were evaluated and verified in actual testing and results were compared with the targeted values.

Improvement in existing products is always a top priority for vehicle manufacturers to remain competitive in the current market. For retaining and potentially increasing market share, vehicle manufacturers are vigilant regarding several trends: market competition, customer expectations and upcoming legislative requirements.

Based on the inputs received regarding these trends, vehicle target specifications were defined. The major parameters critical for an entry-level vehicle: initial cost, running cost and performance.

This study describes the approach followed to enhance the fuel economy and performance of the vehicle by modifying the base engine—but with lower overall cost. For the purposes of this study, “base engine” is defined as the cylinder block, cranktrain mechanism, cylinder head, valve-train mechanism, timing system and lubrication system.

Business sustainability

Functional parameters were defined in the vehicle target sheet considering business sustainability. Major functional parameters for a vehicle are performance, fuel economy, NVH, ride and handling, comfort and safety. These targets were defined in the vehicle target sheet based on qualitative subjective judgment with respect to the benchmark vehicle.

TABLE 1: ENGINE TARGET SIGN-OFF SHEET

SUB-SYSTEM	WEIGHT TARGET (grams)	COST TARGET (INR)	ENGINE MAX. TORQUE (Nm)	*FUEL ECONOMY (KMPL)
BASE ENGINE	700 ↓	10% ↓	8% ↑ (62 Nm to 67 Nm)	14.2% ↑ (19.7 KMPL to 22.7 KMPL)

* Vehicle level target

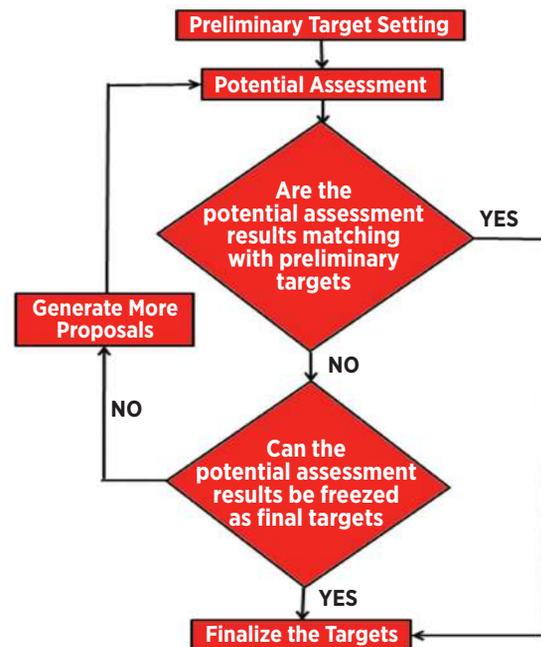


Figure 1: Target-setting decision tree

Some of the key drivers during product conception stage:

Fuel economy: Alto is an entry-level market leader and this segment is highly sensitive to vehicle fuel economy. Gasoline prices in India are high and fluctuate. Improved fuel economy is one of the major attractions for this segment to reduce running costs.

Initial cost: Gasoline vehicles face stiff competition with diesel counterparts due to the lower running cost of diesel vehicles in India. The only lucrative point for gasoline vehicles is the difference in initial cost, which is less than diesel vehicles. Gasoline-vehicle development is focused toward increasing this advantage.

Performance: Improved acceleration and drivability also are vital factors when a new vehicle is introduced as successor of old model. Drivability improvement by improving the low end torque also is important.

Environmental aspects: Reducing tailpipe CO₂, combined with higher fuel economy, is a good step for enhancing the vehicle’s environmental profile and becomes more important for the best-selling model in India.

Legislative requirements: All the legislative requirements were studied in detail before planning changes. Of particular importance were emissions regulations for India and export markets, OBD-II protocols and crash regulations.

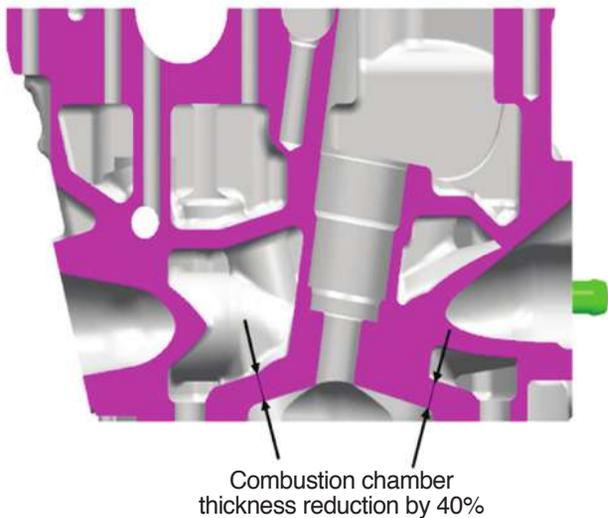


Figure 2: Cylinder head cross-section

Target finalization:

Results of the potential assessment were compared with the preliminary targets and the gap analysis was done based on the decision tree shown in Figure 1.

Many proposals were a tradeoff between fuel-efficiency impact and cost impact and were studied and finalized in an iterative manner per the decision tree.

Design finalization

For the upgraded Alto 800 engine, all targets were determined and signed off as seen in Table 1. These targets were quantified in comparison to the old engine, with upside arrows indicating an increase compared with the prior engine and downside arrows indicating a decrease from the prior engine.

All the design proposals finalized were worked out for detailed study. Major proposals which were worked out and finalized were categorized in the following two areas.

1. Thermal efficiency improvements:

- Compression ratio: increase by 12%

Cooling efficiency improvements:

- Optimized wall thickness via 40% reduction of cylinder head combustion chamber
- Addition of by-pass circuit in cylinder head water jacket
- Cylinder-head gasket coolant hole optimization
- Addition of a knock sensor

2. Mechanical efficiency improvements:

- Lighter-weight crankshaft and connecting rods
- Lighter-weight piston with short skirt
- Low-tension piston rings
- Reduced-width bearings
- Low-viscosity engine oil

Figure 3: Cylinder head bypass union location

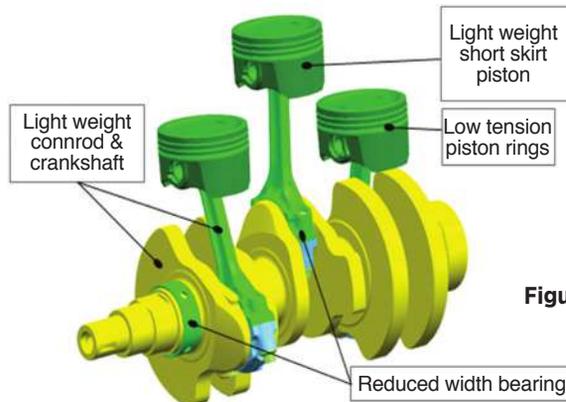
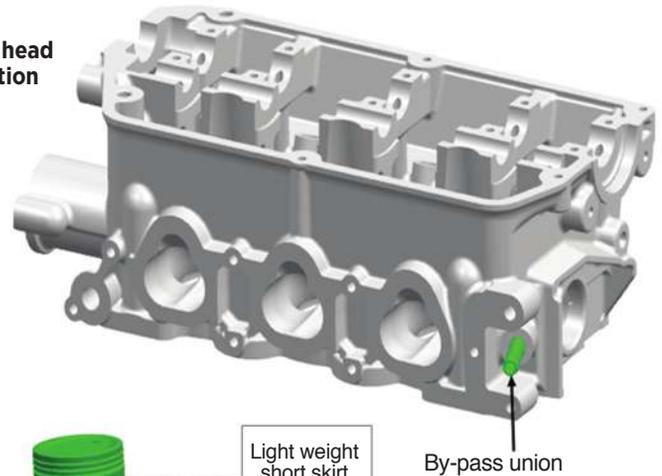


Figure 4: Cranktrain changes

Thermal efficiency improvements:

A major target of this program was fuel-efficiency improvement, therefore the base engine was refined considering this target as a chief priority. Compression ratio plays a major role in improving the thermal efficiency of an engine.

Thermal efficiency can be improved by increasing the compression ratio, so compression ratio for this upgraded engine was increased by 12%. Increase in compression ratio, however, also increases the tendency for engine knock. Countermeasures to mitigate knock were addressed in component design.

Cylinder head combustion chamber: Cylinder head combustion chamber thickness was reduced by 40% to facilitate heat transfer from combustion chamber to water jacket (Figure 2). Temperature in the combustion chamber wall was reduced by 27°C by reducing the wall thickness.

Addition of bypass union: Air trapped in the cylinder head water jacket reduces the efficiency of heat transfer, as bubble formation takes place. Therefore it was necessary to remove this air from water jacket area for the improvement of cooling efficiency. Location of air trap was identified and provision was made to remove the air from that location with the help of by-pass circuit. Temperature in the combustion chamber wall was further reduced by 3°C with the addition of by-pass union.

Cylinder head gasket: Flow velocity and direction of coolant in the cylinder block and cylinder head is of great importance. Flow of coolant from the cylinder block to the cylinder head is controlled through the passages of the cylinder head gasket. Passages of the cylinder head gaskets were redesigned to optimize the flow in water jacket. Temperature in the combustion chamber was further reduced by 5°C with the use of a modified cylinder head gasket.

Knock sensor: A knock sensor was specified for the new engine and provision was made to mount it on cylinder block. With the use of a knock sensor, the engine can operate near its maximum brake torque point without producing knock.

Base-engine value engineering for higher fuel efficiency and enhanced performance

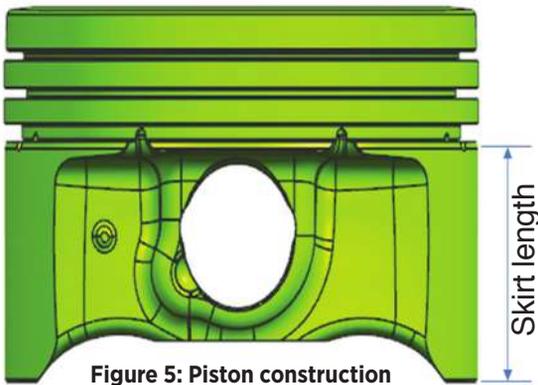


Figure 5: Piston construction

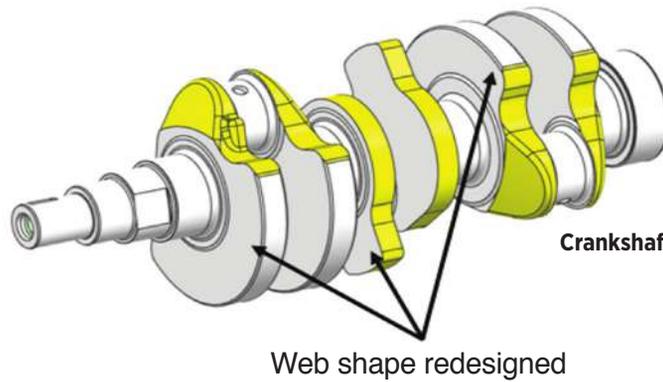


Figure 6: Crankshaft construction

Mechanical efficiency improvements:

Cranktrain assembly: Mass reduction of moving parts reduces inertia forces, in turn directly contributing to energy savings, as less fuel is required to overcome the inertia forces. Cranktrain parts (crankshaft, connecting rods, piston assemblies) combine for a major portion of frictional losses in an engine.

Piston and ring assembly: Pistons were redesigned to meet the higher compression ratio requirements. To reduce hydrodynamic friction, piston skirt length was reduced by 32% in comparison to the previous engine. Weight reduction of 6% was achieved to reduce reciprocating mass. CAE was done before finalizing the design specifications and fatigue strength was verified on actual part-level testing. Meanwhile, ring pack tangential loads play a major role in sliding friction, so tension for the first and second rings was reduced more than 40% and oil-ring tension was reduced more than 50% without compromising oil consumption and blow-by performance.

Connecting rods: Connecting rods were redesigned to sustain higher compression pressure and firing loads due to increased compression ratio. The major modification was the change from a nut-type design to nutless design. Weight reduction of 9% was achieved as compared to previous engine.

Crankshaft: Crankshaft weight was reduced by 7% by redesigning the counterweights. Pin and journal fillets were upgraded to improve the bending fatigue life.

Bearings: Hydrodynamic friction was further reduced by modifying the crankshaft journal bearing and connecting rod big-end bearings. Width of the crankshaft main journal bearing was reduced by 6% and con rod bearing width was reduced by 11%

With all the changes in the cranktrain area, crankshaft frictional rotation torque was reduced by 35%.

Engine oil: Engine oil was changed from 20W40 to 5W30, with hydrodynamic friction reduced by using the lower-viscosity engine oil. Engine parts durability was ensured with the new oil through parts wear analysis and engine oil analysis.

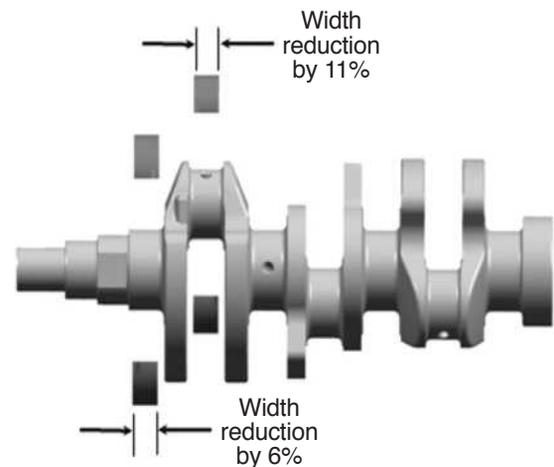


Figure 7: Bearing width reduction overview

Design sign-off

Successful design validation approves the part specifications which will be able to meet the engine-level and vehicle-level targets. Engine-level actual results were reviewed against the target values, with the Alto 800 base engine summary shown in Table 2.

The Table 2 results summarize the successful achievement of all targets. Design sign-off was done with all concerned agencies for the formal go-ahead for mass production.

Conclusion

Continuous improvement in existing engines can be efficiently achieved with a value engineering approach. When a significant number of parts or components are involved and modifications are complicated, the value-engineering approach can be combined with the product-development cycle. The integration of product development with value engineering ensures the achievement of specified targets in a systematic manner and within a defined timeframe. ■

This article was condensed for *Mobility Engineering* from SAE technical paper 2013-01-2748, authored by Narinder Kumar, Anil Kant Bharti, and Amit Gautam of Maruti Suzuki India, Ltd.

TABLE 2: DESIGN SIGNOFF SHEET

	WEIGHT (grams)	COST (INR)	ENGINE MAX. TORQUE (Nm)	*FUEL ECONOMY (KMPL)
TARGET	700 ↓	10% ↓	8% ↑ (62 Nm to 67 Nm)	14.2 % ↑ (19.7 KMPL to 22.7 KMPL)
ACHIEVED	1289 ↓	10.1% ↓	11% ↑ (62 Nm to 69 Nm)	15.2 % ↑ (19.7 KMPL to 22.7 KMPL)

* Vehicle level target

Integrated system engineering for valvetrain design and development of a high-speed diesel engine

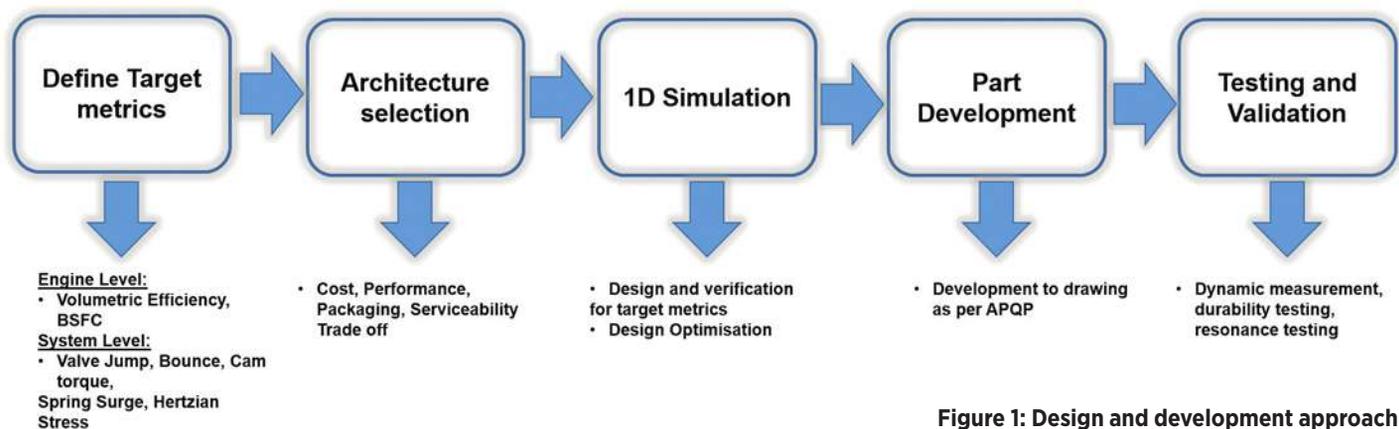


Figure 1: Design and development approach

Introduction

With vehicle emissions norms becoming more stringent and a global focus on CO₂ reduction, there is an increasing need for original equipment manufacturers (OEMs) to develop engines that are smaller and more efficient. The industry thus can expect an increasing trend in engine design toward downsizing and weight reduction.

The demand for increased specific output dictates a robust valvetrain design that facilitates effective engine breathing. In this study we discuss a novel approach to the design and development of a valvetrain system for a 1.0-L high-speed diesel engine, as described in Fig. 1.

Target metrics

Engine functional (volumetric efficiency, BSFC); valvetrain performance (valve jump, bounce) and system reliability (spring surge, Hertzian stress) requirements were defined by a top-down approach to achieve a reliability of 99.97% with a 90% confidence.

Architecture selection

Valvetrain architecture was decided to best suit the target architecture by considering operating, service and reliability factors. The table in Fig. 2 summarizes the considerations for architecture finalization.

Based on the initial study of all configurations, the Type 2 configuration was determined to be best suited to meet cost, packaging and performance tradeoffs. Due to the inherent nature of a diesel engine's combustion bowl design, the architecture demanded a vertical or near-vertical valve configuration.

A robust-engineering approach was applied to the customized 1D model of the engine air system in MATLAB software to decide between a 2-valve or 4-valves-per-cylinder layout. An L16 Taguchi array was built to study the engine-performance effects of 2-valve and 4-valve architecture and a 4-valve-per-cylinder design ultimately was found to be the optimal choice for the chosen engine configuration, with due consideration of BS VI design protection as well as flexibility to scale to a 1.2-L displacement.

Hydraulic lash adjusters as an end pivot with optimum rocker ratio were chosen to suit camshaft positioning and to make the system insensitive to lash. Assembled camshafts were employed in the system architecture to further reduce valvetrain rotating inertia and maximize friction reduction.

Integrated system engineering for valvetrain design and development of a high-speed diesel engine

Parameter	Type 1	Type 2	Type 3	Type 4	Type 5
Cost	2	4	3	5	1
Packaging	2	3	4	5	1
Friction	5	1	2	3	4
High speed capability	2	1	3	4	5

Figure 2

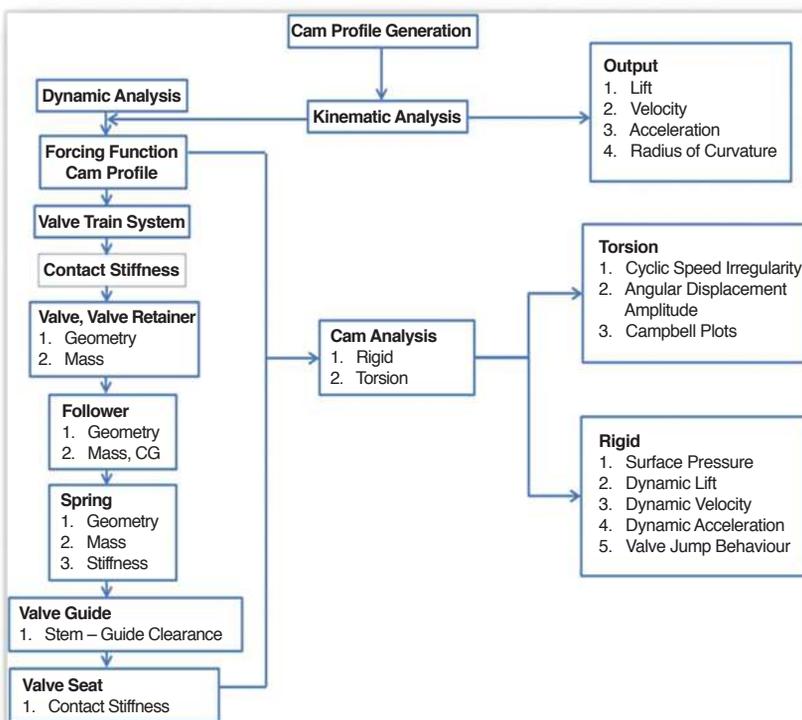


Figure 4: 1-D simulation methodology

Methodology

1D simulation: After selecting the appropriate valvetrain architecture, an in-house detailed design of experiments (DOE) was conducted using the GT-POWER module of GT-Suite software to determine the optimized valve timing and valve diameter (see Fig. 3).

The cam profile was designed with the required target valve timing and valve-lift parameters and system dynamic target metrics in GT VTRAIN (another module of the GT-Suite software) using the conventional n-Polynomial method after the thorough analysis of different methods of cam-profile generation; Fig. 4 shows the detailed process followed in cam-profile generation and analysis.

Meanwhile, spring stiffness directly affects valvetrain friction and critical speed. Spring stiffness sensitivity analysis and finalization was done based on the approach shown in Fig. 5.

Analysis and results

The in-house designed cam profile was thoroughly analyzed for its kinematic and dynamic characteristics. For kinematics, the continuity of

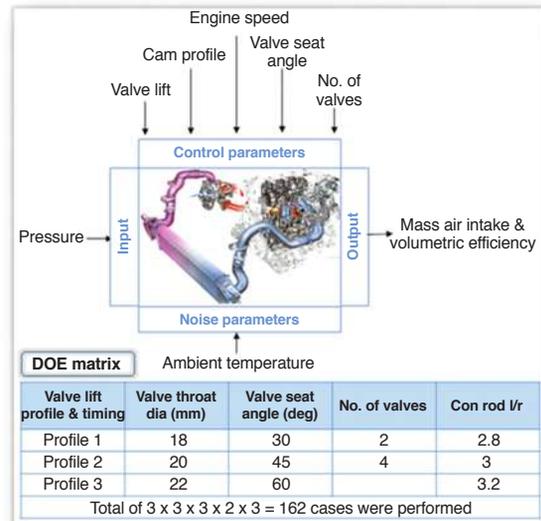


Figure 3: System parameterization and DOE

the profile up to the fourth derivative of the lift was ensured. Quasi-dynamic analysis helped in fine-tuning the stiffness of the valve springs for friction optimization, while at the same time maintaining sufficient spring margin at higher rpms. In dynamic analysis, system dynamics target metrics were verified.

Sufficient optimization was done to move valve jump and bounce rpm well beyond the critical operating speed of the engine. To avoid premature failure of valve springs due to inter-coil vibrations caused by valvetrain excitation, spring surge analysis was performed to ensure the spring natural frequencies were not excited by the engine/valvetrain harmonics throughout the operating range. Torsional frequency analysis was done to understand the valvetrain response to a forced frequency analysis.

Camshaft angular vibration (AV) is a function of crank speed fluctuations, cam torque and timing-drive system response. The driving functions in the analysis were the valve lift profiles and speed variations of the crank system. Dominant order of vibrations as well as their amplitudes also was analyzed; this helped to optimize the noise, vibration and harshness (NVH) characteristics of the valvetrain system.

Since the engine configuration had fuel injection pump (FIP) driven by a separate lobe on the camshaft, the camshaft & FIP torques were computed individually—and upon thorough analysis were phased accordingly to reduce camshaft-drive friction and effective tension in the timing-drive system, all leading to improved system NVH.

Product capability

Results from the dynamic analysis then were statistically analyzed to understand the

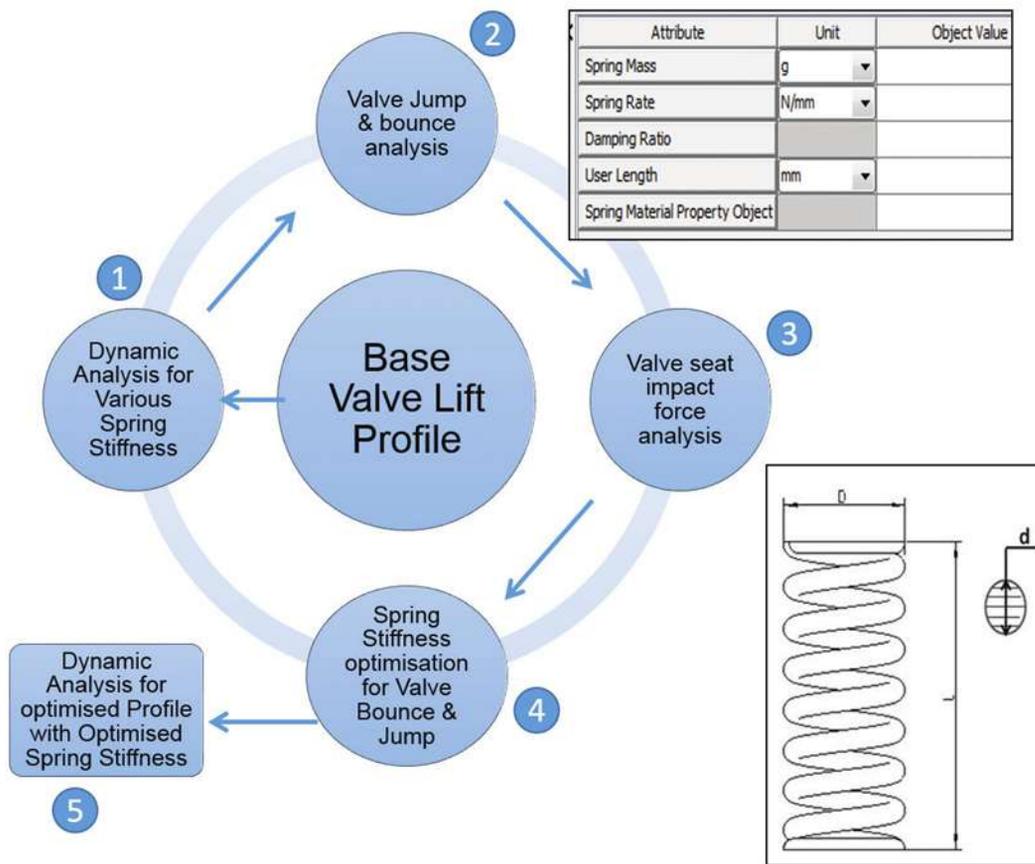


Figure 5: Spring stiffness analysis

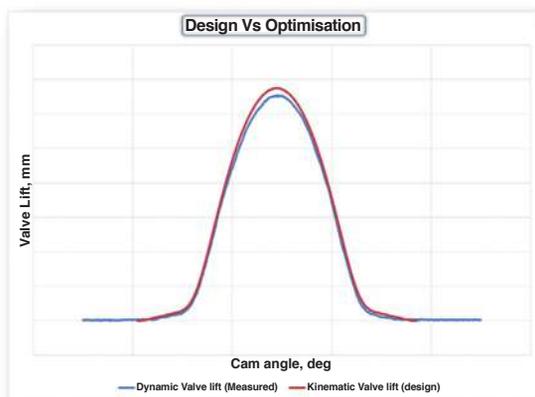


Figure 6: Simulation vs. Measurement

variation. The distribution of peak velocity, acceleration and deceleration over a range of rpms was studied; this helped to control the variations of system behavior over the range of operating points.

Measurement and testing

After thorough analysis through simulation, the designed cam profile was verified through dynamic measurement (courtesy Eaton India). The cylinder head was instrumented to detect valve motion and loads coming onto the valvetrain; Fig. 6 shows the correlation between designed valve lift and actual valve lift.

After verification of the cam profile, the

valvetrain system was subjected to rigorous testing under both firing and motoring test conditions. The response of the valvetrain system to durability testing, resonance testing and high-speed testing then was analyzed and validated.

Summary

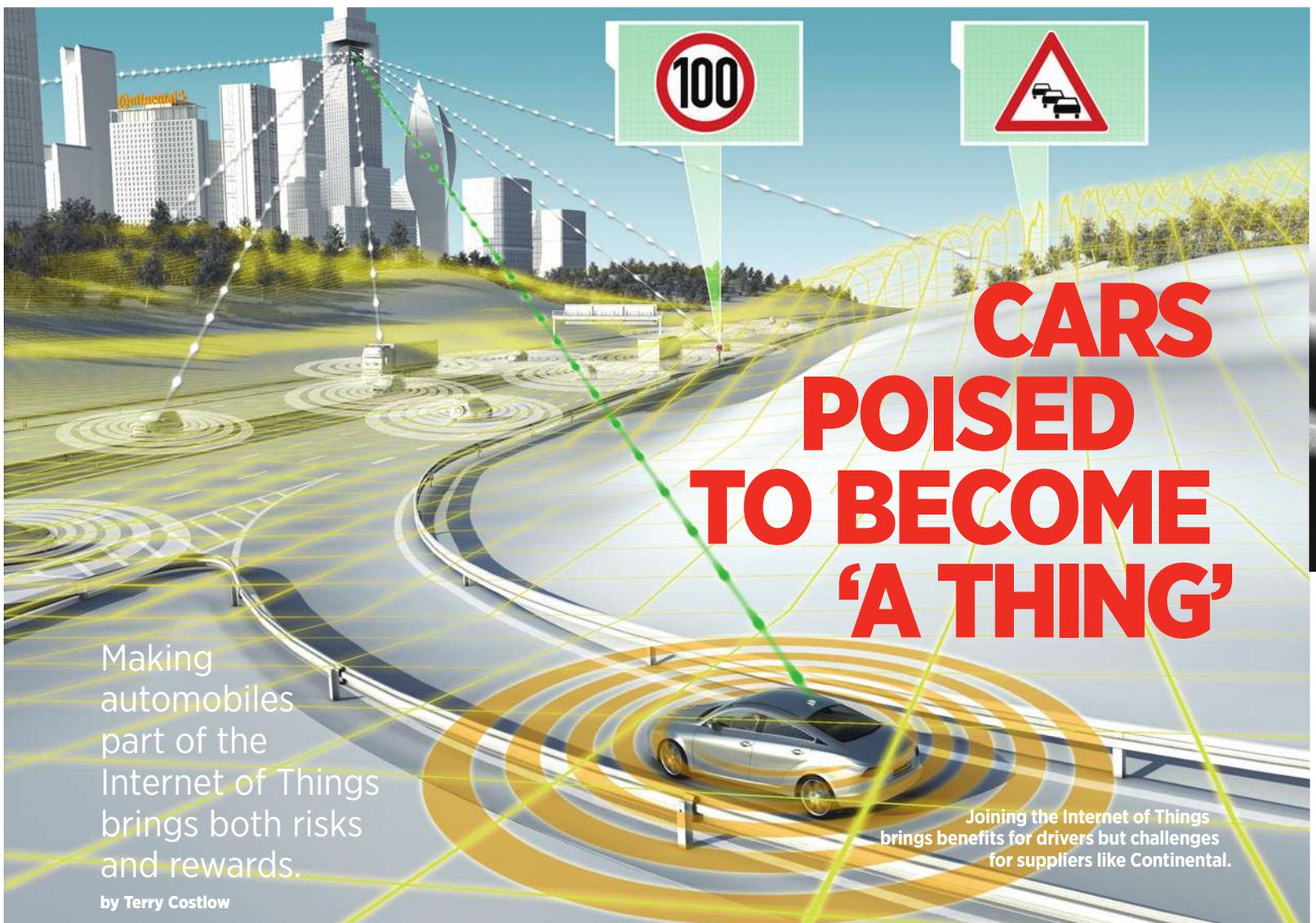
The lead time for engine development has reduced significantly with the advent of advanced simulation techniques. The approach discussed here helped in development of a robust valvetrain system in a very short lead time and with “first time right” results.

Use of 1D simulation helped to optimize the system from architecture selection (choosing cam follower offset, FIP lobe positioning, etc.) to performance (improving volumetric efficiency and combustion). The test results correlated well with simulation, enabling robust projection of product capability.

The supplier collaboration and key product characteristics understanding led to process capability with a defined reliability through data. The subsystem (engine motoring test) and engine dyno resonance durability testing successfully proved engineering life of 250,000 km. ■



Authors: Mr. D. B. Sriprakash, manager, powertrain, Hindujatech; Mr. K. Balasubramani, powertrain system engineer, Hindujatech; Mr. Manoj Muthurethinem, lead engineer, Hindujatech; and Mr. S. Bharathan, powertrain system engineer, Hindujatech



Making automobiles part of the Internet of Things brings both risks and rewards.

by Terry Costlow

CARS POISED TO BECOME 'A THING'

Joining the Internet of Things brings benefits for drivers but challenges for suppliers like Continental.

The Internet of Things (IoT) will be the next transformational aspect of connectivity, enabling machines to communicate with each other without human intervention. Autos are becoming a major player in the IoT era, talking to cloud computers and potentially to other vehicles.

IoT connectivity requires automakers to adopt common standards and rely on independent service suppliers. This openness brings significant benefits—but also risks.

“While the benefits of the connected car are undeniable—enabling features like cloud-based services, downloadable apps, integration with personal devices of consumers, and vehicle data analytics—unwanted intrusions are becoming a growing concern as hackers have an increasing number of entry points into the car,” said Alon Atsmon, Vice President of Technology Strategy at **Harman**.

The high bandwidth of 4G LTE has made it practical for cars to communicate even in rush-hour traffic when cell phone usage is high. Many information technology suppliers are gearing up to support vehicles and machines that will all have phone numbers or URLs. This trend’s already well underway.

“At the end of 2014, in the US, there were 355 million wireless subscriptions with a population in the US of 320 million,” said Joe Averkamp, Senior Director of Technology and Technical Strategy at **Xerox**. “There are more cell phones in use than people, meaning machines, including vehicles, are connected.”

Monthly costs may be one gating factor for automotive’s links to the Web. OEMs may not offer free connections for a vehicle’s lifetime, and consumers won’t pay for vehicle connections unless they perceive value. Cellular providers are already creating plans for machines, which

typically don’t send huge amounts of data.

“Machine-to-machine plans are typically used for smart-home power meters, home security systems, and other IoT types of functions,” said Robert Gee, Head of Product Management, Software & Connected Solutions at **Continental Automotive**. “These plans are also suitable for remote vehicle services such as remote vehicle status like diagnostics, location tracking, or remote door unlock. The automotive industry would certainly benefit from low-cost plans.”

The connected-car era is still in its infancy, but the transportation industry is already a leader in machine-to-machine communications. Many commercial vehicles already utilize the Web.

“Automotive is at the forefront of IoT,” said Scott Frank, Marketing Vice President at **Airbiquity**. “There’s a high level of network connectivity for service delivery and increasingly to take data from the car. There’s also a lot of activity in vehicle fleets.”

Bright outlook

The cloud may eventually become a principal factor for many vehicle features and functions. Activities as diverse as voice control, infotainment and safety can be improved by leveraging

A growing number of vehicles will have phone numbers or Web addresses, according to Xerox.



Automakers are already working with Airbiquity and others to add functions and access the cloud.



the vast capabilities of remote servers.

“The cloud and connectivity can be leveraged to enable services that would not be possible on the vehicle systems standalone,” said Michael O’Shea, CEO of **Abalta Technologies**. “Take natural language processing. This is much more effective when done on the cloud where vast computing resources can be leveraged. Similarly, we can take advantage of huge content databases to enable users to consume virtually unlimited content, such as music, on demand.”

IoT connectivity will eventually play a major role in both the push to autonomous driving and the drive for more infotainment options. Cloud services can offload many functions so on-vehicle electronics can focus on real-time computing.

“The in-vehicle head unit cannot manage

everything, it has limited capabilities,” said Pradeep Seetharam, Director of Programs at **Excelfore**. “Non-latency sensitive decisions like slowing down the vehicle for an upcoming intersection can be made in the cloud. Moreover, for older vehicles with connectivity, more services can be added, like updating navigation and providing location-based services.”

Many observers believe clouds and connectivity will reduce the need for dedicated vehicle-to-vehicle (V2V) communications. These links can provide many low-latency benefits, which can improve safety during the long startup cycle that will occur if or when regulators mandate V2V technology.

“V2V is a huge requirement,” said Shrikant Acharya, Excelfore’s CTO. “Consumers want safety that can be delivered through V2V. But V2V does not have a critical-mass of deployment. By integrating with web services, most V2V can be delivered now.”

Seeking transformers

The Web’s transformative nature will alter many aspects of vehicle design and usage. Human-machine interfaces (HMIs) will have to evolve,

Knocking back hacks

Automakers are hoping to accomplish something that’s vexed leading corporations and government agencies: prevent hackers from breaking through their security walls. Some developers are going outside the vehicle to add more layers to defense schemes.

Design teams are attempting to bake security into every aspect of electronic controls, from concept stage through over-the-air updates that occur over the vehicle’s lifetime, in order to prevent a seemingly endless list of potential troubles that could occur if hackers figured out how to take control of vehicle electronics.

The cloud and cellphones are being enabled with technologies like firewalls, secure operating systems and encryption. Some vendors want to communicate with the cloud to ensure that some instructions are from authorized sources.

“The vehicle should never act on an unexpected, unsolicited external request such as unlocking doors,” said **Continental Automotive’s** Robert Gee. “Instead, the vehicle should receive a request for action, it should establish secure communication with a known server before

identifying the requested action. Another safeguard is to store only necessary information in the vehicle. For example, credit card and other personal data may be stored on a secure server, not in the vehicle if it is not needed there.”

Others propose using two steps to verify user identities. Cellphones could be used to reduce the chance of intrusions.

“When entering the vehicle, the vehicle will interrogate the user’s cellphone to confirm who the user is and then allow access to the vehicle systems and the user data,” said Joe Averkamp of **Xerox**. “In this way, a user’s information cannot be compromised unless the hacker can get access and control of both the vehicle and the user’s cellphone.”

Cellphones can also be used to bring some level of connectivity to cars that don’t have built-in modems. Tighter links between phones and cars can bring drivers a broad range of options.

“**Abalta’s** SmartLink, which is used to enable vehicle connectivity via the cell phone for unconnected cars, can enable a completely secure encrypted data link from the vehicle to the cloud



When more vehicles are connected, security becomes increasingly important.

using industry-standard secure connections,” said company CEO Michael O’Shea. “A secure, unhackable link can be maintained between the vehicle and the head unit as long as the phone is used as a gateway.

“If however, the phone is used as a temporary repository for data to be later transferred to the cloud or to the vehicle, or if the phone controls the vehicle in some way, it can be compromised,” he explained.

Terry Costlow

Keeping eyes on the road

Connectivity brings myriad benefits, but it also heightens concern about driver distraction. The challenges of minimizing driver distraction become more acute when smartphone screens are duplicated on center-stack displays.

When telematic links bring information into vehicles, drivers' attention can be diverted by information deemed helpful as well as by the many smartphone apps designed to entertain consumers. Automakers are using Android Auto, **Apple** CarPlay, MirrorLink and **Ford's** SmartDeviceLink to duplicate phone displays on vehicle screens. That will make it difficult to prevent drivers from using apps that aren't designed for safe driving.

"There's always a risk that something will be distracting if it's projected from a portable device," said Andrew Poliak, Global Business Development Director for **QNX** Software Systems. "That raises the questions of who's responsible and who's liable. Some projection

modes present big questions."

There are techniques that only allow approved apps to run on vehicle screens. Many proponents feel this will minimize distraction while giving passengers free rein.

"Technology exists both in vehicles and on other devices, for example programs on many office computers, that can be used to enable only approved functions," said Robert Gee, Head of Product Management, Software & Connected Solutions at **Continental Automotive**. "It will be important to allow unrestricted web surfing and application usage only for those vehicle occupants who are not involved in driving tasks."

Others feel that it will be difficult to prevent drivers and creative app writers from engaging in potentially distracting tasks. That may force



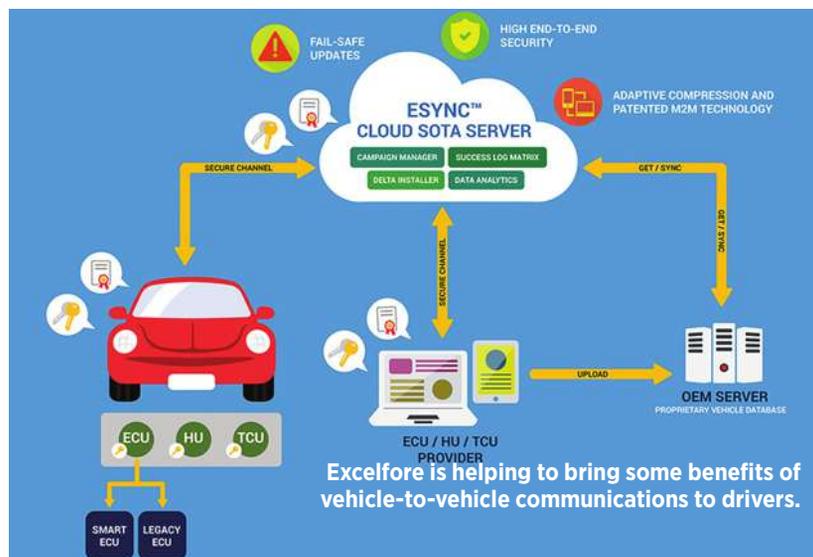
Duplicating cellphone screens on vehicle displays may distract drivers. (QNX)

the industry to alter human-machine interfaces to accommodate connectivity without sacrificing safety.

"It will not be possible to prevent drivers from conducting searches; at least on their smartphones, this will likely be unavoidable," said Joe Averkamp,

Senior Director of Technology and Technical Strategy at **Xerox**. "For searches and other web-based work like seeking entertainment utilizing in-vehicle systems, the key is to provide larger displays, fewer icons, and less-complicated command structures. The system should rely on more audible information, for example e-mail using text-to-speech or speech-to-text."

Terry Costlow



service providers will gain a major role and some business relationships will have to be revised.

"Automakers used to put together a bill of materials, then when the vehicle was sold, responsibility transferred to the dealer," Frank said. "Now when a connected car is sold, the automaker can maintain a relationship with the customer without competing with the dealer. They can leverage that to enhance vehicle performance and service recalls and other software issues."

Data management will also become a major issue. Automakers will be able to gather volumes of information from vehicles, collecting usage data that can be mined for further research. Automakers and drivers alike will be able to use data that moves through the cloud.

"Connecting to the cloud lets you use data from a ginormous sensor," said Andrew Poliak, Global Business Development Director for **QNX** Software Systems. "It also makes it easy to send data back to the OEM and other services. Everything does need to be done with protections for privacy."

Privacy and security are critical aspects of any Web-related technology. In automotive, those factors are complicated by the need to

provide HMIs that help drivers remain focused on safety.

"First, security over-the-air must be established via appropriate encryption and certification," Gee said. "Second, the server system itself must be secure in case the functions provided are driving-related. And third, the cloud-based service itself must be designed with all of the other HMI elements and functions in mind that will be in the vehicle, in order to reduce driver workload and enable safe usage."

Web-based standards are helping automakers alter display imagery so users can customize some aspects of the HMI. These standards make it easier for engineers to adjust visual elements, showing drivers information that suits driving conditions.

"With HTML5, you can easily change the look and feel; an older person who wants big buttons or only a couple radio stations can easily change things," Poliak said. "It's also easier to alter the HMI as speed changes, showing some things at low speeds and different things at higher speeds."

Showing this type of contextual information is also a key to reducing driver distraction. As more driving-related data comes from the cloud, user interfaces are being revamped to make sure information is easy to understand.

"Cognitive overload has a lot to do with how information is presented," Frank said. "As services get more data-intensive, you need to present data in a way that's digestible. That will require changes to the HMI. You don't want to give the driver three options, you want to offer the best one." ■

AGILITY TRAINING FOR CARS



The 2016 BMW 7 Series adjusts its Bilstein Damptronic dampers using information about upcoming road conditions from its GPS navigation system.

Chassis component suppliers refine vehicle dynamics at the high end and entry level with four-wheel steering and adaptive damping.

by Dan Carney

As personal mobility moves toward the perhaps inevitable singularity of automatically piloted pods able to totally isolate passengers from any sensation of the surrounding world, today's manually piloted cars are adding systems to aid with guidance and improve isolation from bumps in the road.

The 2016 **BMW 7 Series** not only features computer-steered rear wheels that assist the driver, but its GPS system uses data on road surfaces to tune the response of the car's air suspension system.

BMW calls this Active Comfort Drive with Road Preview. The system matches the driver's style with a database of the upcoming road surface to firm the suspension when necessary and soften it when possible.

"Exceptional driving dynamics has always been one of the main reasons customers buy this car," observed Klaus Fröhlich, BMW Board of Management member responsible for development. "That is why the new BMW 7 Series offers such a versatile driving experience, from absolute comfort to extremely sporty."

For 2016, the company switched to a faster-acting air suspension in place of the previous hydraulic active dampers to optimize the capability of Road Preview. It also added active anti-roll bars that disconnect when driving in a straight line for maximum compliance, then reconnect when the steering wheel turns. "Its sensitive control guarantees optimum road handling at all times," promised Fröhlich.

The 7 Series' air suspension system also contributes to the car's active ride height, which automatically lowers the car when driving in Sport mode. The driver can also manually raise the car 20 mm (0.8 in) when for example entering steep driveways. It automatically returns to normal height when the car reaches 22 mph (35 km/h).

BMW replaced the previous planetary variable steering device with a variable-ratio steering rack that now works with all-wheel-drive models, unlike the old system. The computer-controlled rear steering system helps by improving steering response when agility is called for and by slowing it down for stability at other times.

Performance applications

Of course, the goal of active suspension isn't always isolation. The **Porsche 911** and **Nissan GT-R Nismo** use **Bilstein's** Damptronic active dampers to give their cars maximum performance, contributing to the GT-R's achievement of a 7:08.69 lap time of the Nurburgring.

Porsche uses a **ZF TRW**-supplied all-wheel steering system in addition to active suspension to optimize the dynamics of the 911. This is important, as the latest iteration of the car rolls on a wheelbase that is 100 mm (3.9 in) longer than before, which could reduce its nimbleness in turns. Porsche credits the rear-steer system with shaving three seconds off the Nurburgring lap time of the 911 Turbo.

A company technical paper describes the system's function in detail, explaining Porsche's

AGILITY TRAINING FOR CARS



The Porsche 918's ride and handling benefit from both Bilstein active damping and ZF rear-wheel steering technology.



The ZF TRW rear-steer system on the Porsche 918 can steer each rear wheel independently of the other, as much as $+3^\circ$ and -1.5° .

rear-steer system controls each of the rear wheels individually, rather than steering them together in parallel, as with the front wheels.

It uses two electromechanical actuators installed where the toe control arms would normally go. The actuators use an electric motor to turn a spindle through a belt drive to a maximum of $+2$ or $+3^\circ$ (depending on the exact model) to -1.5° . For comparison, 2° of angle on the front wheels is the result of 30° of steering wheel rotation.

The rear-steer system points the rear

wheels opposite the fronts at speeds below 50 km/h (31 mph), providing the equivalent response of a car with a wheelbase that is 250 mm (9.8 in) shorter than it really is. For practical parking purposes, the turning circle is reduced by 0.5 m (1.6 ft).

At higher speeds above 80 km/h (50 mph), the rear wheels steer in the same direction, parallel to the fronts, stabilizing the car with the effect of a wheelbase that is 500 mm (19.7 in) longer than it really is. Between the 50- and 80-km/h thresholds, the system continuously switches between steering opposite to the front and steering in parallel with the front, depending on the exact situation.

Another result of using the rear steering system is Porsche's ability to use a front steering rack with 10% quicker response for improved agility.



Bilstein's Damptronic active damper has the appearance of a conventional passive damper.



Tenneco's DRIV semi-active damper is a bit taller than a passive shock because of the self-contained electronics beneath its bumper cap, and a bit thicker in diameter because of the space needed for the solenoids inside.



Tenneco chief engineer for advanced engineering and vehicle dynamics, Dan Keil, says the goal for DRIV semi-active dampers is to achieve 75% of the benefit of more sophisticated systems at half the total cost.

This would make the car's handling potentially twitchy, but with the rear steering able to counteract the front to slow it down when necessary, the 911 and 918 are able to have lightning-quick front steering without making the cars unstable.

Budget future

It is no surprise that Porsche, BMW, and the Nissan GT-R feature advanced technology to improve their driving dynamics. But **Tenneco** aims to democratize active suspension technology by developing a simpler and less costly semi-active damper technology.

The company supplies its Continuously Variable Semi-Active (CVSA) suspension to cars like the BMW 1, 2, 3, and 4 Series, **Volkswagen** Golf, Scirocco, and Passat CC, **Ford** Focus RS, **Seat** Leon, **Volvo** XC90, and **Renault** Espace and Talisman.

But the company is aiming for still less expensive technology that has variable stages of damping it can switch among rather than a continuously variable range as with its CVSA product, explained Dan Keil, Chief Engineer of Advanced Engineering and Vehicle Dynamics.

The company's new DRIV technology targets light truck and compact car applications. "We wanted a simple and easy way to integrate a system with a significantly lower price than CVSA systems, so more customers can enjoy it on vehicles that typically wouldn't have variable damping," Keil said.

The company is testing hardware now that could be on pickup trucks for model year 2020, and it plans to start testing lighter-duty components for cars in the C-segment next year. The benefit of the DRIV adaptive damper system is that the shocks are independent modules that do not require specific systems be integrated into the host vehicle. The dampers carry their own processor circuitry and accelerometer, so there is no central control system.

Tenneco does use an electronic interface module that connects the dampers to the vehicle's CAN bus, but that is the only bit of hardware on the car, and it just connects to the bus to monitor information such as vehicle speed, steering wheel angle, and brake pressure, which it relays to the individual dampers' processors. The DRIV system does not monitor damper velocity, but rather estimates it from the accelerometer and other inputs.

The expectation is that the DRIV shocks will provide 75% of the benefit of a continuously variable CVSA system at half the cost. Some of this cost savings comes from reduced vehicle integration costs and the elimination of dedicated sensors in the car, so the dampers themselves will be more than half the cost of their CVSA counterparts, Keil noted.

Where CVSA is continuously variable, DRIV shocks have three solenoids that switch between two available damping valves to provide eight different levels of damping.

Compared to traditional inexpensive passive dampers, the DRIV shocks are taller, with the computer hardware mounted beneath the bumper cap atop the shock body, and that body is a bit fatter to incorporate the valve solenoids. However, the resulting damper is close enough to a regular one that manufacturers will have no difficulty accommodating its larger size, assured Keil. "I don't think that's going to be an issue," he said.

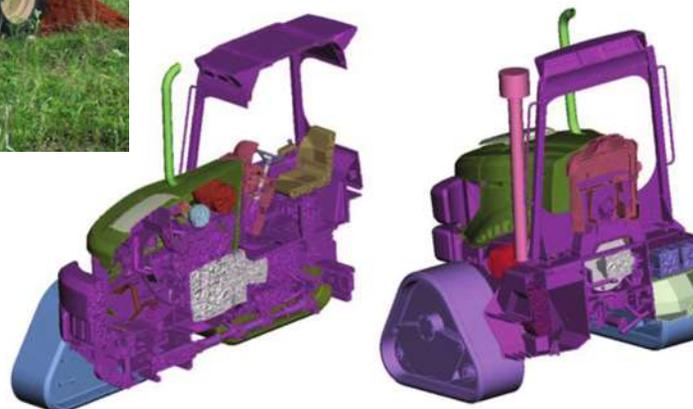
"It will show well on anything that needs improvement from a dynamic standpoint," Keil enthused. "We're very excited to get the first application going."

All drivers will appreciate the improvement to ride and handling available on the full range of vehicle segments too. At least until we're relegated to automated transportation pods. ■

Evaluating thermal design of construction vehicles



Simulations were performed on a Ditch Witch RT120 Quad, a prototype of which is shown above. The extensive use of solid meshing for the thermal mode (pictured at right) to model conduction very accurately is a novel aspect of this study.



CFD simulation is used to evaluate two critical areas that address challenging thermal issues: electronic control units and hot air recirculation.

Design and evaluation of construction equipment and vehicles constitute a very important but expensive and time-consuming part of the engineering process, due to a large number of prototype variants and low production volumes associated with each variant.

Engineers from **Exa Corp.** and **Charles Machine Works** collaborated to investigate an alternative approach to hardware testing. Because of the enormity and complexity of the vehicle design process for off-highway vehicles, the researchers limited the scope of their current study to thermal evaluation of vehicle components only. A CFD simulation provides the surface temperatures of the entire vehicle and the flow domain. However, the focus was on two particular areas that address critical and challenging thermal issues: electronic control units (ECUs) and hot air recirculation which occurs when the vehicle is stationary or at very low speeds and when engine cooling and airflow are provided by the fan only.

Electronic components are challenging since their maximum temperature requirement is relatively low while the thermal environment can be very hostile as a result of heat sources in close proximity. For hot air recirculation, it is possible due to a combination of vehicle geometry and seals for the hot air exiting the heat exchangers to recirculate back to the inlet of the heat exchangers, leading to potentially catastrophic temperature excursions and failure of components.

For the CFD simulations, performed on a **Ditch Witch RT120 Quad** vehicle, a coupling is implemented between the Flow Solver PowerFLOW version 5.0c and the Thermal Solver PowerTHERM version 11.0.4 that

accounts for conduction and radiation effects.

One novel aspect of the simulation is extensive use of solid meshing for the thermal model in order to model conduction extremely accurately, which is very important for the ECUs since they are located in a low airflow environment and conduction is the most important mode of heat transfer for that location.

This operating environment is thermally challenging since the cooling is provided by the engine-driven fan alone and the vehicle is stationary. The flow is strongly dominated by forced convection near the fan and natural convection away from it.

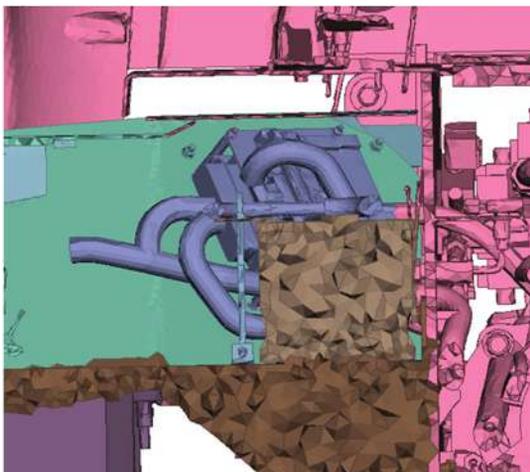
Validation studies where PowerFLOW simulation results were compared to experiments have been documented in prior **SAE** technical papers. Good agreement was observed between simulations and experimental data for both forced and natural convection flows.

Simulation setup

The flow solver is a general-purpose CFD code that uses the Boltzmann Equation to solve for the velocity and pressure field. The turbulence

Fan Speed	2690 rpm
Ambient Temperature	40 ° C
Wind Speed	0.0 m/s
Radiator Coolant Flow Rate	2.69 kg/s
Radiator Heat Rejection	59.9 kW
CAC Inner Air Flow Rate	0.133 kg/s
CAC Inner Air Entry Temperature	185.6 ° C

Vehicle test environment.



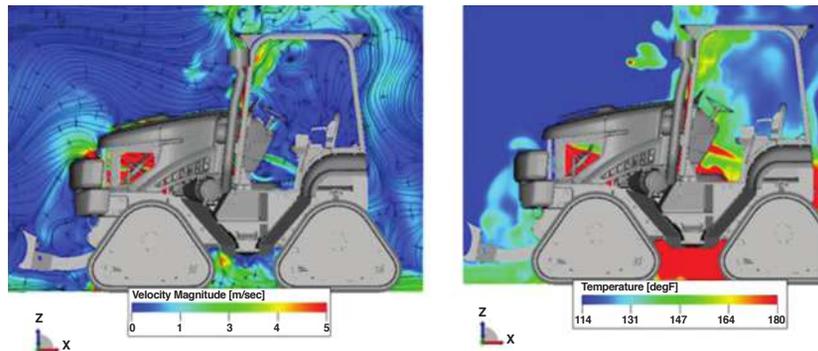
Cross section through ECU compartment showing solid mesh and heat sources on the inboard side.

model employed in the flow solver is conceptually similar to a large eddy approach to turbulence modeling. Recent improvements in modeling the temperature scalar equation have further enhanced the accuracy of the temperature calculations in the flow solver.

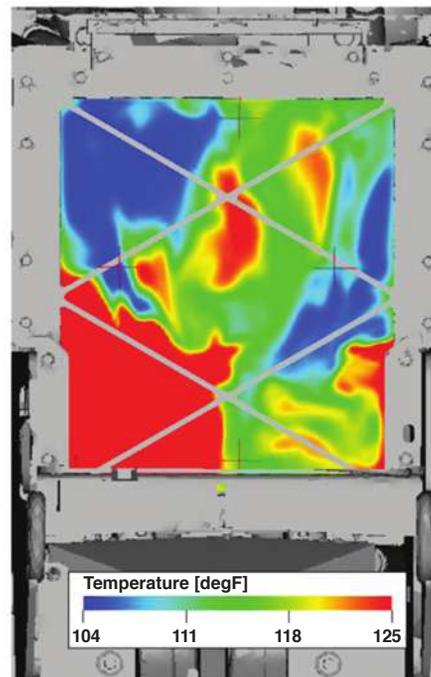
The simulation methodology involves a combination of the flow and thermal solver. The flow solver calculates the flow and temperature fields in a volumetric flow domain, and the thermal solver calculates the temperature in the solid surfaces by taking into account radiation from the surfaces, conduction within the solid surfaces, and convection at the surface.

The current study is, as far as the authors know, the first of its kind that looks into a stationary vehicle with the fan on and is able to accurately simulate the flow and temperature field as evidenced by good comparison with test data. Furthermore, the use of a large eddy-like flow solver with fully transient formulation is not something that has been attempted before for an off-highway vehicle in idle.

Since one of the objectives was to evaluate



Hot air recirculation patterns, y-section velocity and temperature.



Operator Right

Operator Left

Radiator pre-heat distribution. The red crosses indicate the location of the thermocouples in the experiments.

hot air recirculation of the heat exchangers, the geometry of the vehicle hardware between the radiator and the fan was modeled “as is” from CAD and no effort was made to close out small air gaps between components.

The vehicle has four heat exchangers namely the radiator, charged air cooler, and the left and right oil coolers that are each modeled by heat exchanger characterization data. The airflow through the heat exchanger cores on the air side are modeled using the porous media feature of the flow solver. The resistance coefficients for the porous media were based on measured pressure drop versus flow rate data.

The vehicle was stationary and all the cooling was provided by the rotating engine fan. The rotating fan was accurately modeled using the sliding mesh capability of the flow solver.

Thermal model

For the thermal model, accurate inputs of thermal material properties for different vehicle components are required. Material property inputs are thermal conductivity, density, specific heat, and surface emissivities.

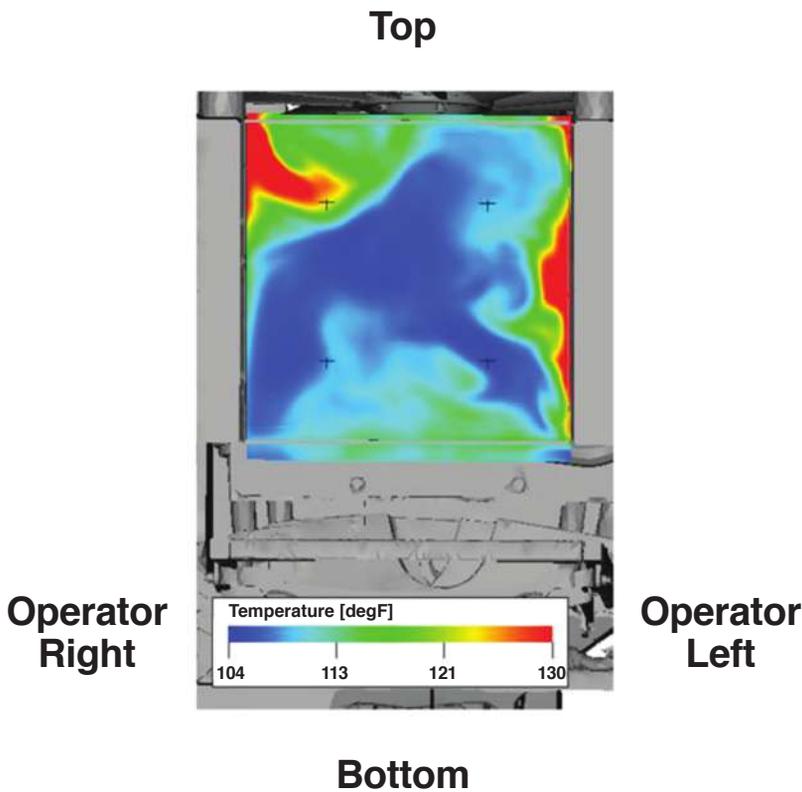
Evaluating thermal design of construction vehicles

Parameter	Unit	Test	Simulation	Difference
Coolant Exit Temp	[°F]	210	214	4
Average Pre-Heat (Points)	[°F]	+7	+6.25	-0.75

Radiator coolant temperatures.

	Test (°F)	Simulation (°F)	Difference (°F)
Top Middle	109	113	4
Bottom Middle	113	109	-4
Operator Right	111	112	+1
Operator Left	111	107	-4

Comparison of radiator pre-heat temperatures.



Charge air cooler pre-heat distribution. The black crosses indicate the location of the thermocouples in the experiments.

The heat sources were modeled as prescribed temperatures that were obtained from supplier-provided test data. To accurately model conduction, 2D shell elements and 3D tetrahedral elements were used for the entire thermal solver model.

The extensive use of solid elements is a novel feature that was done to account for the conduction paths in a more complete manner for a complex 3D geometry and hence accurately model thermal conduction for the solid parts. For earlier studies using coupled thermal simulations, thermal conduction was modeled using 2D shell elements with prescribed part thicknesses. This approach worked well for thin parts such as thermal shields with relatively simple conduction paths; however, for this study, not all thermally critical parts could be approximated as thin parts and therefore 3D solid elements were used for the thermal solver.

For this study, the critical parts are the ECU units and batteries located under the step. The ECU unit and battery are shielded from the heat coming from the inboard side by seals, insulation, and frame rails that separate the hot inboard side and the ECU compartment.

The insulating layer that separates the hot inboard side from the compartment is not thin and has complicated conduction paths that make it difficult to model conduction accurately using 2D elements alone. Therefore, 3D tetrahedral elements were used to model conduction.

Simulation results and test comparisons

The vehicle is in the idle regime wherein the fan is rotating but the vehicle is stationary with no wind velocity assumed in the simulation or observed in the test environment. The experiments were performed in a test chamber at Charles Machine Works. The temperature measurements were made using thermocouples, which were accurate to within 2°F (1.1°C).

It is important to validate the results and gauge the accuracy of the simulation. The temperature distribution in a vertical plane upstream of the radiator provides a good visualization of the pre-heat that is caused by recirculation. Note that the ambient air is 104°F (40°C). All the pre-heat was found to be a result of recirculation of hot air.

Good agreement is observed between the experiments and that of the simulation. The difference in the temperatures is close to the experimental uncertainty of the measurements, which is estimated to be 5°F (2.8°C). Given other input uncertainties, the difference of less than 10°F (5.6°C) between simulation and experiments is “good.”

The difference of 4°F (2.2°C) of the coolant temperatures between the experiments and simulation are within the experimental uncertainty. Note that the fan rpm, which is assumed as constant in the simulation, fluctuates by up to 4%, which leads to a 5°F fluctuation in the coolant exit and entry temperatures as per sensitivity studies with Flow Solver.

For the temperature distribution in a horizontal plane upstream of the charge air cooler, good agreement is observed between the experiments and that of the simulation with the exception of the bottom left location where the pre-heat is under-predicted. Geometry mismatches, in particular with the seals, are a possible cause of this inconsistency. Good agreement is also observed for

	Test (°F)	Simulation (°F)	Difference (°F)
Bottom Left	130	108.5	-21.5
Top Left	110	105	-5
Top Right	107	109.5	+2.5
Bottom Right	123	117	-6

Comparison of charge air cooler pre-heat temperatures.

Parameter	Unit	Test	Run 4	Difference
Inner Air Exit Temp	[°F]	153	147	-6
Heat Rejection	[BTU/min]	999	926	-7.3%
Inner Air Delta T	[°F]	213	219	6
Avg Pre-Heat (Thermocouples)	[°F]	+14	+6	-8

Comparison of charge air cooler inner air temperatures and heat rejection.

the charge air cooler inner air temperatures and heat rejection.

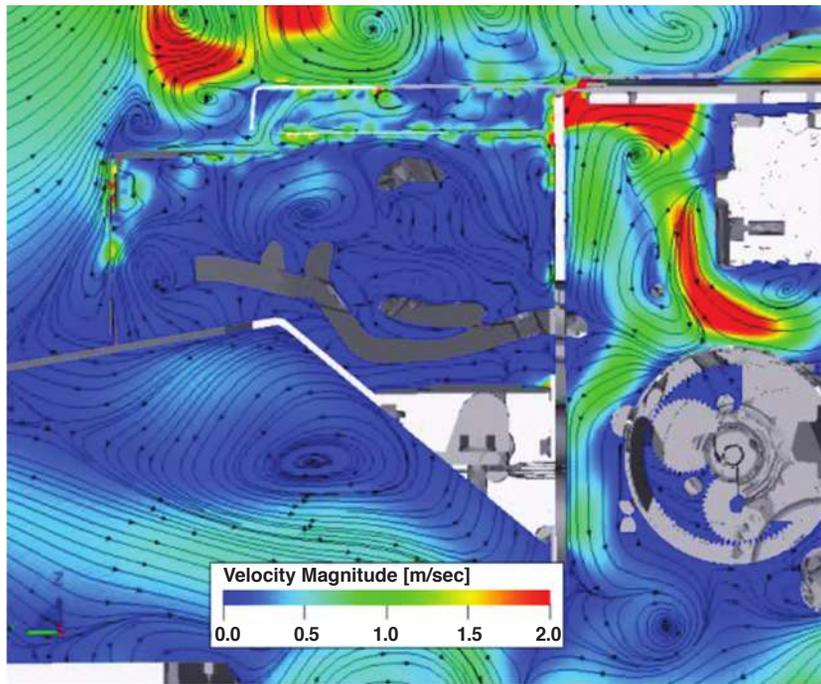
Within the ECU compartment, which is located under the step near the hydraulic tank, the velocity levels are quite low, as shown along an x-section; therefore, temperature distribution is dominated by conduction since convection levels are low on account of low velocities.

Researchers observed that the high temperatures are on the inboard side of the ECU compartment and the compartment is heated primarily from the hot air temperatures in the inboard side that is transported via solid conduction through the frame rails.

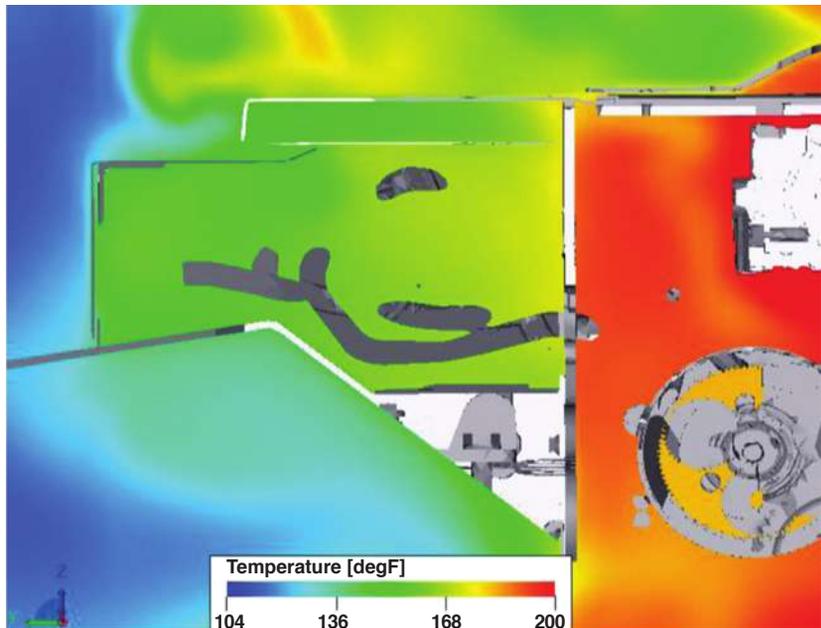
They also observed a temperature gradient in the y-direction of the compartment. The temperature drops by 12°F (6.7°C) as it moves outboard 450 mm (17.7 in) in the plus y-direction. The temperature gradient observed compares well with the test data, where a temperature gradient of 1°F (0.6°C) was observed over a distance of 40 mm (1.6 in).

For temperature distribution in a y-section, the test thermocouple measurement was 150°F (66°C) and the simulation reported a temperature of 156°F (69°C). Therefore, good agreement was observed, taking into account the uncertainty of the thermocouple location and that temperature gradients were observed in the compartment air.

The average surface temperature distribution for ECU1 (upper) at 166.9°F (74.9°C) and



Velocity distribution in an x-section through the ECU compartment.



Temperature distribution in an x-section through the ECU compartment.

ECU2 (lower) at 161.7°F (72.1°C) reveal that both ECU components meet the requirements of maximum temperatures of 180°F (82°C). The test thermocouple measurement on the surface of ECU1 was 162°F (72.2°C). Therefore, good correlation is observed between test data and simulation for surface measurements.

In addition to the promising results, the total time required to set up and run the simulations is very reasonable and could reduce time and cost of the engineering design process for off-highway vehicles. ■

This article is based on SAE Technical Paper 2015-01-2888, doi:10.4271/2015-01-2888, by Mukutmoni, D., Donley, T., Han, J., Muthuraman, K. of Exa Corp., and Campbell, P., Mertz, T. of Charles Machine Works.

Global VEHICLES

Tesla's highly-anticipated Model 3 brings technology questions



Baby Model S? Model 3's styling with blunt, sans-grill nose fits nicely into Tesla's growing portfolio. (Photo by Tod Mesirow)

The ravenous feeding habits of the 24-hour news cycle rarely turn toward automotive transportation, and usually only when a disaster has happened, such as **Toyota's** acceleration mess or **Volkswagen's** diesel cheating. Recently it was **Tesla Motors'** turn to feed the beast with the unveiling of its long-anticipated Model 3, the battery-electric compact sedan which had successfully remained under cover because Job One still is almost two years away.

"Traditional" automakers don't normally lift their skirts quite so early in the development process, when the mules are still circulating as taped-together Franksteins with shear-cut holes. But here were three glossy Model 3s, perhaps the only driveable examples in existence, giving rides to the 650 or so attendees at a boisterous launch party behind the headquarters of **SpaceX**, Tesla's sister company in Hawthorne, CA.

The car that Tesla CEO Elon Musk promised will arrive late in 2017 as the company's volume play looks like a blunted and bob-tailed version of Tesla's larger Model S. It offers five seats and both a conventional trunk and a "frunk" (front trunk) situated above a choice of battery packs that will deliver, said Musk, at least 215 mi (346 km) of range on the EPA cycle.

Analyzing the early details

With a base price of \$35,000, but with pricier and faster variants in the pipeline (almost assuredly using 2-motor drive-lines), the Model 3 is claimed to be a sub-6-s 0-to-60 mph (0-to-97 km/h) sprinter. It's also a fashionable way to carry a 9-ft (3-m) surfboard—a design attribute highlighted by Musk.

Other notable features: a giant pane of rear glass that curves up and over the heads of the rear-seat passengers; a single, center-mounted 15-in (381-mm) touch screen that replaces all conventional dash gauges and controls; **SAE** Level 2 fast charging via the company's Supercharger network; and Tesla's Autopilot self-driving capability as standard equipment. Technical details at the unveiling were slim as expected; the platform is said to be an evolution of the Model S and the



View from the backseat shows the minimalist IP and large touchscreen display that replaces all buttons and knobs. The Model 3 is wide for a C-segment vehicle, but rear seat legroom is in short supply. (Tod Mesirow)

body materials described as a "mix of aluminum and steel."

During the brief test ride, in which patrons were rocketed up and down a nearby street that was sealed off by the police, *Automotive Engineering* touched a magnet to various places on the car, including the structural B-pillar, and got no "stick"—either these early prototypes were made of fiberglass or there's very little steel in the body top-hat.

While Tesla engineers have previously talked about a potential mixed-materials strategy as they push future product development down the retail-price ladder, the prospect of an aluminum-intensive Model 3 raises the question of how profitable a \$35,000 EV will be when it carries 60-80% of the battery capacity of the basic \$71,200 Model S 70.

And yet to be confirmed is the car's battery-cell form factor. Will Model 3 be the first Tesla to abandon the 18650-type "laptop" lithium battery cells used in Model S and X packs, in favor of the prismatic or pouch-type form factors that are increasingly becoming the automotive standard?

Musk promises a car that will have more cabin and cargo space than anything its size, which is roughly that of a **Mazda3**. The Model 3 is indeed wide, but the high, flat floor and the



Launch party crowd outside the SpaceX facility check out the Model 3's enormous rear window-cum-roof panel. (Tod Mesirow)



One of the prototype Model 3s at the March 31 unveiling was fitted with a new-look “aero” wheel. (Tod Mesirow)



Arena rock and religious evangelism meet the auto industry: The Model 3 (at left on the stage) debuted inside a hangar-sized SpaceX building in front of 650 Tesla true believers. (Tod Mesirow)

imposing front seat shells create a shortage of legroom in back. He might be right about the interior volume number, but only because there’s a trunk where most cars have an engine.

The Model 3 seems unlikely to weigh less than 4000 lb (1814 kg), given Tesla’s current size/mass ratio in which the Model S weighs about 4800 lb (2177 kg) and the Model X closer to 5500 lb (2495 kg). That will make it a very heavy compact car indeed.

Riding on charisma

The Model 3, asserted Musk, is the affordable electric car that he got into the car business to build. “For all those who bought an S or an X,” he told the Hawthorne crowd, “thank you for paying for the 3.” Tesla marches to its own beat, and unlike the Model S and X unveilings which have been chaotic cheer-fests attended by thousands, the head-count at Hawthorne was limited and the security was airtight. As usual, Musk had gathered his acolytes to both dazzle them with another product “leap” and also warn about the perils of climate change and the need to reform carbon-based transportation.

Tesla’s CEO spoke for barely 20 minutes, without a prompter and completely improvised, stuttering a bit and sometimes



Tesla CEO Elon Musk promised Model 3 will enter production at the company’s Fremont, CA, plant by late 2017. (Tod Mesirow)

breaking thought to go in a different direction or answer a call from the crowd. Perhaps no person in American public life today connects with a crowd using so many multi-syllable words. And no other car company depends so heavily on the charisma of its chief for its future survival.

Attendees at the unveiling had traveled on their own dime from as far away as Europe with barely two-weeks’ notice after responding promptly to a mass email invite. They repeatedly stated their confidence that Elon Musk “does what he says.” He will deliver the Model 3 in 2017, it will be \$35,000 (to start), and it will do all the things Musk says it will.

However, many of the Telsanauts also see completely different charm points in the Model 3. For example, Jaff Toth and Cindy Stevenson, a Model S-owning couple from Toronto, are keen on the EV’s environmental angle, noting that with Niagara Falls contributing to Ontario’s clean power percentage, an electric car has a definite green sheen. Meanwhile, Will and Jessie Harris, who came from Denver, were all over the Autopilot function. They eagerly await the day when they can send deliveries from their two pizza restaurants via self-driving vehicles.

Rob Sunn



Tesla engineers have dubbed the Model 3’s front cargo trunk the “frunk.” A magnet probe of the cars’ exterior panels during the launch showed no indication of ferrous metals. Number on the back wall indicates how many customers had plunked down a \$1000 deposit on the car, sight unseen, when this photo was taken. (Tod Mesirow)

New Komatsu wheel loader with Tier 4F engine consumes 13% less fuel



By optimizing control of engine power and improving powertrain and hydraulic efficiency, the WA600-8 consumes up to 13% less fuel than its Tier 3 predecessor.

Equipped with an EPA Tier 4 Final certified engine, the new WA600-8 wheel loader from Komatsu combines an enhanced lockup torque converter function and SmartLoader logic to achieve low fuel consumption and high travel speeds. It now incorporates many of the features of the smaller construction class wheel loaders such as KOMTRAX, upgraded cab features, and improved operator comfort, Bruce Boebel, Senior Product Manager, Komatsu America Corp., told *Off-Highway Engineering*.

"This model represents the largest Komatsu construction class model and is the transition point between use at smaller quarries and large mines," Boebel said. "It can be used for v-cycle work or equipped with a load-and-carry spec. Various tire and bucket options make it highly adaptable to many customer operations and applications."

By optimizing control of engine power and improving powertrain and hydraulic efficiency, the WA600-8 consumes up to 13% less fuel than its Tier 3 predecessor. To aid worksite productivity and machine efficiency, engineers designed a new bucket that reportedly fills easier, retains material better, and

provides better visibility. The standard bucket capacity increased to 9.2 yd³ (7.0 m³). An enhanced auto-dig function reduces the operator effort required to fill the bucket.

"The new Komatsu bucket has an improved profile, allowing for a 7% increase in capacity versus the WA600-6 buckets," said Boebel. "The new auto-dig feature helps less experienced operators be more productive faster."

Powering the new wheel loader is a 23.15-L, 529-hp (395-kW) SAA6D170E-7 engine, which incorporates a Komatsu Variable Geometry Turbocharger, heavy-duty EGR (exhaust gas recirculation) system, and Komatsu Crank Case Ventilation filter.

Designed in conjunction with the engine are the Komatsu Diesel Particulate Filter (KDPF) and other after-treatment components like the SCR (selective catalytic reduction) system and the DEF (diesel exhaust fluid) mixing tube. More than 98% of KDPF regeneration is performed passively, with no action required of the operator and no interference with machine operation.

Komatsu's SmartLoader Logic, combined with the large-capacity lockup

torque converter that activates in 2nd, 3rd, and 4th gears, provides optimal engine torque for improved acceleration, hill-climbing ability, a higher top speed—25.5 mph (41.0 km/h) vs. 23.4 mph (37.7 km/h) for the previous WA600-6—and fuel savings. Another fuel-saving function is Auto Idle Shutdown, which reduces idle time.

"All of the Komatsu wheel loaders have Power and Economy operating modes to match the power to the job. While testing in E mode, Komatsu has seen up to 13% less fuel consumption as compared to the WA600-6 model," Boebel said.

To improve traction on various ground conditions, the WA600-8 features Variable Traction Control and a modulated clutch system. "The modulation clutch allows smooth speed control to load trucks, controls tire slip, and reduces driveline shocks without slowing work equipment hydraulic speed," Boebel said.

"With significant enhancements in production capacity and fuel economy, the WA600-8 is designed to maximize production efficiency in loading off-highway trucks or load-and-carry



To improve traction on various ground conditions, the WA600-8 features Variable Traction Control and a modulated clutch system.

applications,” said Rob McMahon, Product Manager for Komatsu America. “Full rear fenders with steps and handrails at both sides of the machine add convenience for daily inspections.”

Among many factors influencing development, customer feedback played a “pivotal role,” according to Boebel. “For example, the addition of the handrails on both sides of the machine was the direct result of customer input.” The WA600-8 was a multi-year project that involved rigorous testing and machine validation.

Asked about any major development challenges, Boebel replied, “Anytime that there is a major redesign in a model, real estate always becomes a major challenge. How do you add space for aftertreatment systems, an additional walkway, and other new components but still have excellent access and maintainability? Komatsu engineers met that challenge. Access is excellent on this machine.”

Features that aid maintenance and access include a swing-out cooling fan with wider fin spacing and reversing fan for easier cleaning, a sight gauge at the DEF fill cap to help prevent overfilling, and additional hinged panels at each side of the machine to ease access to regeneration components.

In-cab enhancements compared to the previous model include a high-back, air-suspension heated seat with cast frame members that reportedly softens machine vibrations for operator comfort. Electronic pilot control levers with F-N-R switch are seat-mounted for convenience.

The KOMTRAX Plus telematics system and monitor provides key machine



Engineers designed a new bucket that reportedly fills easier, retains material better, and provides better visibility. Bucket capacity is 9.2 yd³ (7.0 m³).

metrics, including KDPF status and DEF level data, fuel consumption, plus performance information collected and sorted by operator ID.

The 7-in high-resolution monitor is full color and visible even in harsh light, the company claims. A separate, full-color rearview monitor comes standard and improves line-of-sight. This model is also the first to include an integrated load meter that is incorporated into the monitor and KOMTRAX, said Boebel. Data is available on the machine monitor and remotely via the web.

The WA600-8, along with every Komatsu Tier 4 Final construction-sized machine, is covered by the Komatsu CARE program for the first three years or 2000 hours. This program includes limited scheduled factory maintenance, a 50-point inspection at each service, and one complimentary KDPF exchange in the first five years. Select labor, fluids, and filters are also covered.

Ryan Gehm

Lockheed Martin LM-100J starts taking (a similar) shape

Wing production for the first Lockheed Martin LM-100J commercial multi-purpose freighter has begun in Marietta, GA, which is also home to the C-130J Super Hercules final assembly line. Other structural parts are in production at the Aeronautics sites in Meridian, MS, and Clarksburg, WV, facilities. The LM-100J is expected to make its first flight in 2017, then enter into an FAA certification phase.

The LM-100J will be the civil-certified version of the C-130J and an updated version of the L-100 (or L-382) cargo aircraft, and will be “the only commercial airlifter that offers all-terrain and all-weather service,” according to George Shultz, Vice President and General Manager, Air Mobility & Maritime Missions at Lockheed Martin. Those qualifications will allow the LM-100J to deliver cargo in both developed and rugged environments, as well as support multiple missions, from firefighting to medevac to VIP transport. Lockheed says 115 L-100s were produced from 1964-1992, with about 55 still in service.

There’s no denying that the LM-100J shares a bloodline with the C-130J, one of the main exterior differences being the lack of lower windows under the windscreen on the LM-100J. Those windows allow C-130J pilots to look ahead and down to see drop zones. The civil version will have the same Dowty R391 propellers with six scimitar-shaped composite blades and a black de-icer boot at the base of the vertical fin.

A second, though optional, visible external difference between the LM-100J and the C-130J “seems to be counterintuitive” says Lockheed: the installation of 18 small, lightweight, strake-like devices called “microvanes” on each side of the aircraft’s aft fuselage near the cargo ramp door and horizontal tail.

These roughly 10-in long vanes create minimal localized drag. However, working as a group, the microvanes slow the natural, much larger drag-creating vortex that forms as airflow goes over and under the wing and swirls around the aft end of the aircraft. The net result is described by the company as “a 15-count reduction in drag at long range cruise speeds, which equates to

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Lockheed Martin's LM-100J will incorporate technological developments and improvements over the existing L-100s that resulted from years of C-130J operational experience, including more than 1.3 million flight hours by operators in 16 nations. (All images Lockheed Martin)



ASL Aviation Group signed a letter of intent for up to 10 LM-100Js at the 2014 Farnborough International Airshow.



In January 2014, Lockheed Martin officials submitted a Program Notification Letter to the FAA for a type design update for a civil-certified variant of the C-130J Super Hercules.

about a 25 gal/h saving.”

Internally, the LM-100J, like the C-130J, features an Enhanced Service Life, or ESL, center wing box, enhanced icing protection, and other reliability and maintainability improvements that are a part of the basic C-130J design.

Four **Rolls-Royce** AE2100D3 engines will be on the LM-100J, just as the C-130J. The FADEC engines are rated at approximately 4637 shaft hp each, or roughly 150 hp more than the legacy **Allison** T56 engines. The engines are expected to exceed **FAA** Stage IV standards, so there will be significantly less fly-over noise with an LM-100J than with an L-100.

The LM-100J and C-130J will share the same automatic engine thrust control system, which adjusts for asymmetric thrust conditions—if one engine

loses power, the other engines automatically compensate to keep the aircraft flying safely.

On deck in the two-pilot cockpit will be **Northrop Grumman's** low-power color weather and ground-mapping radar data that can be displayed on any of four head-down color displays. All primary flight information, including altitude, heading, and airspeed is presented on two see-through head-up displays in the crew's field of view. The LM-100J, through the digital autopilot/flight director can take the aircraft down to Category II minimums, generally considered 100 ft decision height for landing with 1200-ft visibility. The flight deck will have a standard microwave oven, like on the C-130J. However, the inclusion of a coffee maker is just optional.

To be of use as a commercial air

freighter, some lightweighting of the aircraft is necessary, so nearly all of the military-specific hardware found on a C-130J will be removed or disabled on the LM-100J. Some military-specific software functions, such as a computer-aided release point (CARP) for air-drops, will be retained.

Crews flying the LM-100J will generally fly single-ship operations, so the low-voltage formation lights on the C-130J will not be installed, as is the Station Keeping Equipment, or SKE, which is necessary for formation air-drops with the C-130J.

Rather than sound-deadening and temperature-controlling insulation blankets used on C-130s, the LM-100J will have a hard liner that is essentially like a bedliner in a pickup truck—able to withstand repeated bumps and scrapes without requiring regular repair or maintenance.

The LM-100J avionics system includes a commercial Traffic Collision Alert System; the latest-generation CNS/ATM equipment and software; commercial takeoff and landing data; and GPS position data reported to the aircraft's emergency locator transmitter.

Structurally, the LM-100J will have reinforced bird strike plates around the windscreen and a commercial standard, bird-resistant windscreen. Externally, the LM-100J will have an INMARSAT radio and commercial GPS antenna on the top of the fuselage.

Because much of the flight test done to civil certify the C-130J in the late 1990s will be directly applicable to the LM-100J, testing and certification of the newest Hercules variant is expected to take about twelve months.

Jean L. Broge

2017 Pacifica is first hybrid minivan, rides on all-new FCA platform

Despite the popularity of SUVs and CUVs, nothing beats a minivan for its combination of interior flexibility, ingress/egress, passenger comfort, cargo hauling and, in some cases, fuel efficiency. While the segment isn't as large as it was in 2000, when sales peaked at 1.37 million deliveries in North America, about 500,000 minivans are still sold annually—ample profit-spinning volume that analysts expect will be sustained through at least 2020.

As millions of customers would likely attest, the minivan is “still the best transportation ‘tool’ for families,” observed Tim Kuniskis, head of FCA’s passenger car brands, when he pulled the cover off Chrysler’s 2017 Pacifica—the company’s sixth generation minivan. It was shown to *Automotive Engineering* and other media on embargo prior to the car’s official debut at the 2016 North American International Auto Show.

Underpinned by what Chief Engineer Jessica LaFond called “an-new platform designed for this role” (FCA’s global E-segment front-drive architecture), the Pacifica was developed with a focus on best-in-class ride, handling, and NVH attenuation—the latter achieved through great attention to vehicle aerodynamics. There are 37 new features LaFond and Kuniskis described as “innovations.” They include the segment’s first plug-in hybrid powertrain with FCA-developed electrified transmission offering up to 80 mpg equivalent (MPGe) fuel efficiency, hands-free sliding doors, standard active noise cancellation for the cabin, a 360° birds-eye-view camera, and a cleverly reconfigured and easier to use Stow ‘n Go storage system that required a dedicated floorpan.

There’s an optional and removable eighth-passenger seat in the second row that weighs 37 lb (16.8 kg), and a comprehensive electronic features suite that puts Pacifica into the segment’s safety, HMI (with new Uconnect Theater and 8.4-in touchscreen display), and connected-car vanguard.

The overall design injects a “CUV-like character” into the two-box theme that Chrysler has refined continuously since 1984, noted Ralph Gilles, FCA’s global design chief. The segment’s longest wheelbase (121.6 in/3089 mm) enables a “living



Pacifica cockpit has more storage solutions than previous model.



The Hybrid version of the all-new 2017 Chrysler Pacifica features subtle styling differences compared with its non-hybrid cousin. Note charging port door on the left front fender.



Rear-sloped C-pillar, the strong A-line on the bodysides, and integrated upper rear spoiler are distinctive styling cues of the new Pacifica (Hybrid model shown).

room on wheels” interior package with seating for eight as described by LaFond. Overall length is 203.6 in (5172 mm)

Mixed-metals mass reduction

The Pacifica’s claimed coefficient of drag (Cd) is .300, which engineers claim is best in class. It is the result of 400 h of scale-model and full-size work in FCA’s wind tunnel, along with a claimed 1.2 million CPU hours for CFD development. CdA is 9.95. Active grill shutters are a segment first and help reduce drag on average by 10% at highway speeds.

The body is also strong and mass efficient. LaFond’s development team in Auburn Hills, MI, achieved a 30% gain in body torsional stiffness while reducing total vehicle mass by about 250 lb (113 kg), compared with the outgoing model (RT program) that debuted in 2008.

“We really optimized the new high-strength and advanced hot-stamped high-strength steels,” she said, with about 22% more HSS in the 2017 vehicle than its predecessor. Use of structural adhesives to replace mechanical fasteners and welds was increased on the program. LaFond also noted the team’s “extensive” FEA work to create an engine box that optimizes packaging, strength and predictable deformation, to meet the IIHS’s 25% narrow offset crash test.

With the additional feature content that was certain to increase Pacifica’s curb weight over the previous-gen vehicle, mass reduction was a “big detail focus” within the development program, she explained. There’s a magnesium cross-car beam, and Pacifica’s exterior panels include the first aluminum

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8.4-in touchscreen is centerpiece of new UConnect HMI.

sliding doors on a Chrysler minivan. The rear liftgate uses a magnesium inner and aluminum outer panel.

The hydroformed front suspension cradle is solid-mounted at six points, and features octagonal side rails in thin-wall HSS, with lightening holes strategically placed. The front MacPherson strut suspension is aluminum intensive, with forged lower control arms, cast knuckles, and an extruded aluminum cross member for the electric steering gear. Aluminum also is key to reduced mass in the engine brackets and rear upper shock mounts.

Also, the use of rebound springs inside the rear shocks enabled the rear stabilizer bar to be eliminated. The chassis team is proud of a new rear trailing-arm design, rendered in thin-gauge steel to save mass.

The independent rear suspension module mounts on an isolated, full-perimeter type steel cradle, also using lightening holes to save weight.

Attacking NVH

Pacifica's segment-longest wheelbase, combined with ample vehicle width (79.6 in/2022 mm) and wide front/rear track—68.3-in/1735-mm for non-hybrid models and 68.2-in/1734-mm for hybrids—creates a 200 ft³ (5.66 m³) interior volume, which LaFond claims is best in class and also has segment-leading



The optional tri-pane sunroof is a segment exclusive for Pacifica.



Yes, a 4 x 8-ft sheet of plywood will fit inside Pacifica with both seat rows stowed and the liftgate closed.

front legroom, she said.

NVH countermeasures are designed to address root causes and noise paths, LaFond explained. Air leakage into the passenger compartment is attenuated to around 225 CFM. The 5.0-mm acoustic laminate windshield glass delivers a claimed 2.5 to 3.0 dB improvement over standard tempered glass. All doors feature triple sealing and the wheelhouse liners are specially designed to muffle road noise. Engineers said wind noise in the Pacifica is as low as 63 dB at 70 mph. The vehicle's Articulation Index (speech intelligibility; 0%=worst, 100%=best) is above 84% at 70 mph.

Pacifica also features a standard active noise cancellation system that uses the audio system and four strategically located microphones to introduce opposite-wave sound to the cabin as an offset to unwanted sounds. Engineers said the system also enables more fuel-efficient engine calibrations due to the reduced need for NVH-related tradeoffs, and reduces the need for acoustic-damping material that adds unwanted weight.

Segment-first hybrid drive system

Pacifica's power comes from both conventional and Atkinson-cycle (for the hybrid model) versions of FCA's newly invigorated 3.6-L Pentastar V6 (see <http://articles.sae.org/14322/>). A stop-start system will be added later in the 2017 model year. The conventional non-hybrid version is coupled with the ZF-Chrysler 9-speed planetary automatic.

In 3Q16 the Pacifica Hybrid debuts as the industry's first electrified minivan. With an estimated 248 hp (185 kW) produced by its Atkinson-cycle, 12.5:1 compression V6, the vehicle will deliver an estimated EV-only range of 30 mi (48.2 km).

Centerpiece of the new hybrid driveline is FCA's in-house designed electrically-variable transmission (EVT). The unit, long in development (and of which more will be described in a future article), uses two electric machines, both of which are capable of driving the vehicle's wheels thanks to a one-way clutch. The 16-kWh lithium-ion battery is packaged under the second-row seats.

The vehicle has provision for SAE Level 1 and 2 (via combo connector) charging.

Lindsay Brooke

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Q&A



'Supercars' and character are critical in the autonomous future

At the recent New York auto show, *Automotive Engineering* spoke with Keno Kato, Nissan's Corporate Vice President for Global Product Strategy & Product Planning. Kato, an enthusiast of mobility in just about any form, was in town to support Nissan's unveiling of the heavily revised 2017 GT-R supercar.

Everyone knows the GT-R is a halo car. But the GT-R almost transcends that description in your home market, doesn't it?
I raised the question about this car to check awareness. Nearly 100% of people know it; awareness is unbelievable. For my generation—and a bit younger as well as much older—this (GT-R) brand is significant. Maybe like Corvette in the U.S. This is truly the icon of high-performance (in Japan) for my generation. For the future, we have to continue to demonstrate our technology and our performance through this brand.

So one way you see the GT-R is as a demonstration of Nissan's ability to solve problems?
It's a symbol of our technical capability. Plus, respect for the customer. If we start to make excuses, that's really bad. (Nissan can cope) with any new requirement, regulation, anything—that message is very important.

What does this mean when the talk almost every day is about how cars are going to drive us? Will there always be a place for a GT-R? Will someday even a GT-R be autonomous?
There's zero "mismatch" (between performance cars and autonomous technology). There's an easy example: in the city, in traffic, the driver can reduce effort. After leaving the city and getting to the destination, say the racetrack, the driver resumes control. This is quite a straightforward story for even the GT-R—or any car: reduce effort for the driver in unfavorable traffic situations. That's most valuable. I've tested an (autonomous) prototype, by the way, and I was excited. I am

a car guy and I was excited by the thought of the autonomous technology.

You think there is good potential, then, to meld the aspects of performance and autonomous? That the two worlds are not mutually exclusive?

Making the decision to use autonomous technology for the GT-R would (actually) help a lot. Why? Because performance cars have no space, (autonomous hardware) is heavy, system response (is critical)—putting that technology in any performance car is helpful (to speed development for mainstream models). Packaging is really the key.

What about "connected" vehicles and the user experience? You've mentioned that many aspects of advanced-driving technology should be the same, perhaps even set by regulation.

To provide the right answer for the customer, there will be massive commonization in (non-critical) areas. The customer is waiting for that. Like autonomous driving: in traffic, less effort. Then on track day, let's enjoy (each model's individual character and control feedback).

Are you confident there will be that sort of uniformity in the future vehicle's user experience?

For some areas. Unfortunately, since it's driven by car manufacturers—there's no stronger power to control it, no leadership. But I shouldn't say that! (laughs). There have already been some examples of commonization, such as charging infrastructure.

I'm a big fan of American "muscle" cars. They shared engines, they shared frames, they shared everything—except (body) style. "Fast N' Loud," "Overhaulin'"—I love those American TV programs. And Chip Foose is great. Okay: (it's mostly about) beautiful design. I'm always thinking about the appeal of those vehicles: sometimes it's very subtle differences. But still, people enjoy that difference, rather than, "no, no, no, the lever *has* to be here."

And nicknames for each engine. So lovely. People—not only Americans, by the way—love a simple differentiation. Wheelbase is the same, engine is the same. Same, same, same—but with a different style.

Back to the GT-R. There are a lot of hybrid supercars now. How do you feel about electrification for supercars?

I cannot speak about the future GT-R plan. But observing the competition and other similar vehicles, it seems to me to be quite a normal solution to meet requirements. Very natural and normal. Or—there may be other ways. Aerodynamics, or...

And the accelerating pace of electrification for mainstream vehicles?

It is the future, no question. (An EV) is fun to drive. And if we don't have to go to the gas station—oh, wow! (laughs)

I have a 2-stroke motorcycle. Smoke. The combustion is not so efficient. But I don't want to sell this lovely 2-stroke motorcycle. To compensate (for occasionally using it), maybe I should own an EV. For daily commuting, the EV is very good.

Bill Visnic

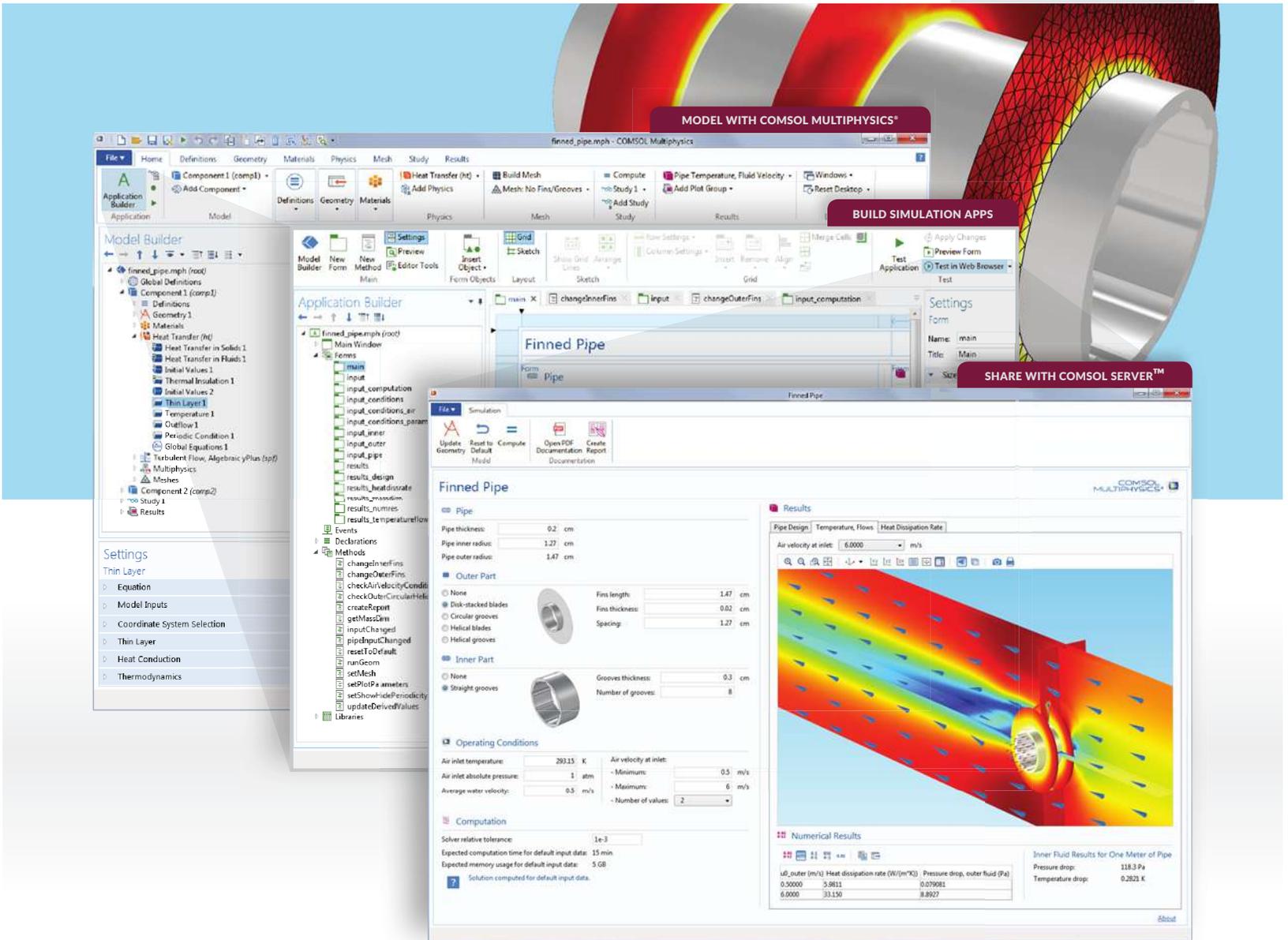
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