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Volume 3, Issue 3

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CONTENTS

Features

Cover

Mahindra & Mahindra breaks into the United Kingdom with its electric e2o City car, not only to challenge Europe's largest EV market with this aggressively-priced, battery-powered runabout—but also to experiment with an Internet-based sales model.

CONTENTS

Departments

Smalley Wave Spring

Coil Spring

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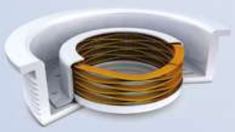
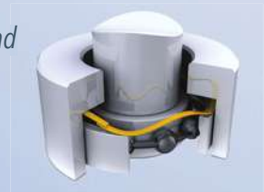
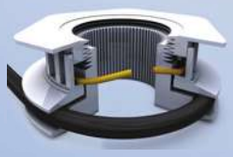
Crest-to-Crest® Wave Spring



Bearing Preload Wave Spring



Round Wire Wavo® Spring



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EDITORIAL

Autonomous-technology development deals with a chilling downshift

The entire world heard about the May death of a **Tesla** driver in the United States, widely acknowledged as the first-ever fatality involving a vehicle using autonomous-driving technology on a public road.

Any vehicular-related death is a tragedy, but one fatality on any day on U.S. roads typically isn't news. The attention riveted on the crash of this autonomously-traveling Tesla demonstrated the globally pervasive public interest in autonomous-vehicle technology. Why? To most people, self-driving cars are the stuff of profound science fiction—yet they're now being told the technology is ready, right now, to transform everyday life.

And up until the May crash in Florida, that's certainly the perception Tesla had created around its "Autopilot" functionality.

Tesla quickly admitted the accident was the result of the car's machine-vision camera and software failing to distinguish the white trailer of a semi-truck from the brilliant white-sky background. That was the "technical" cause, if you will. But critics contend the "real" cause of the crash was that the driver was goaded into overconfidence in dangerously unproven technology.

In an instant, this single crash pivoted the autonomous-car dialogue from a comparatively benign and innocent question of "Gee whiz, engineers, when will it be ready?" to a more-accusatory, "Hey, you told us this is the way to go—but people are getting killed."

Just like that, the rush to introduce autonomous technology has experienced its own crash: into the reality of global consumer-product safety.

The concussion waves from the Tesla crash have expanded rapidly. In late July, **Mercedes-Benz** canceled U.S. television commercials that gave the impression the new E-Class sedan essentially can drive itself (the commercial can be seen here: https://www.youtube.com/watch?v=C0d5e1c_qo0). "Is the world truly ready for a vehicle that can drive itself? Ready or not, the future is here," the ad teases, as the E-Class pulls out to pass Mercedes' famously avante-garde F 015 concept car and the E-Class driver grandly removes his hands from the steering wheel.

Months before the Tesla crash, **General Motors** confirmed it had decided to delay the introduction of its "Super Cruise" semi-autonomous driving functionality slated for the 2017 **Cadillac** CT6 flagship. As more details of the Tesla crash became known, GM's global product-development boss, Mark Reuss, expanded on the Super Cruise delay, telling a Detroit newspaper that the system would function only on roads GM has 3D-mapped via LiDAR technology—and the car's cameras also will be employed to confirm the driver is attentive.

Then at a high-profile auto-industry conference last month in Michigan, Mark Rosekind, administrator of the powerful **National Highway Traffic Safety Admin.**, made it clear his agency plans to step in. First will be "guidelines" for automakers to consider as they proceed with autonomous-technology development. But there will be a more-aggressive role if NHTSA sees automakers getting ahead of themselves.

"We'll be watching. We can regulate whenever we want," Rosekind was quoted as saying to the conference crowd. Whether this was a "threat" from NHTSA—which until recently bore the perception of being too compliant regarding car companies' comittment to safety—is immaterial; until the Tesla crash, regulatory entities had done scant public questioning of autonomous-technology readiness or the pace of its market introduction.

It's been suggested by many good thinkers in the auto industry that the primary concern shouldn't be about whether fully autonomous driving is possible. No, they've said for some time that the crucial issue is how we handle the so-called "middle" stages of the five levels of autonomy as defined by SAE standard J3016 (for an excellent oveview, see http://www.sae.org/misc/pdfs/automated_driving.pdf), in which interaction between driver and automation sporadic. The Tesla crash appears to lend credence to this concern.

It seems it took a coalescing event to cause the industry, regulators—and yes, even anxious-to-adopt car buyers—to pause andd take a breath regarding autonomous technology. Everyone should be sure to make the most of it.

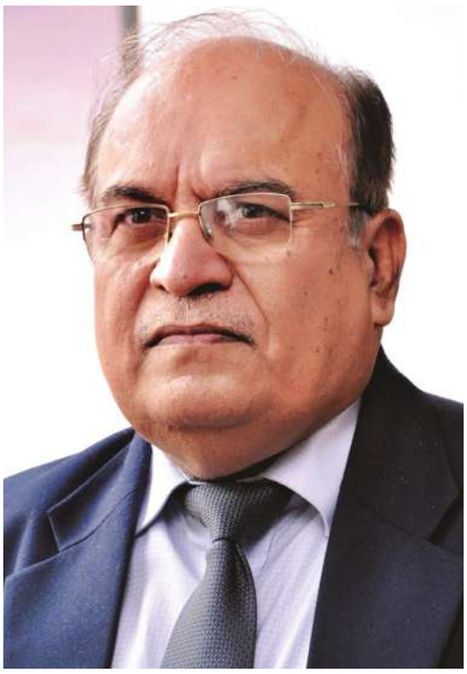
Bill Visnic
Editorial Director

FOCUS

Preparing SAEINDIA for the next phase of expansion

Warm greetings from SAEINDIA!

At the outset, I want to convey sincere thanks to all the members of SAEINDIA for expressing their confidence by nominating me as SAEINDIA President. I consider it a great honor—and at the same time a great opportunity to serve the mobility community in India, including its associates.



Dr. R.K. Malhotra
President, SAEINDIA

On behalf of all members, I'd like to convey our appreciation to departing President Dr. Aravind Bharadwaj for introducing several new SAEINDIA initiatives, such as the Policy Deployment Meet, ITEC INDIA 2015—which has entered into the annals of SAEINDIA as a biennial program—and the Blue Ribbon CXO Conclave. The first-ever meeting of the SAE International Board in India and SAEINDIA's 20th anniversary celebration were highlights among other action-packed events organized during the term of Dr. Bharadwaj.

Meanwhile, this year's SAEINDIA events and programs continue apace. SUPRA SAEINDIA 2016 was recently conducted at the Buddh International Circuit, with a record 124 teams participating. The technical inspection team, comprised of three overseas experts from Germany and one from Russia, certified 26 teams (another record number) to participate in the final dynamic competition. The palpable enthusiasm and the never-say-die attitude of the 2,400-plus students who participated in the event was amazing. The increasing interest of students in our events like SUPRA and BAJA imparts us all with confidence for an even brighter future for SAEINDIA.

We are projecting expansion of professional membership in SAEINDIA to 5,000-plus in two years through organic growth and extension of SAEINDIA with new Divisions, as well as upgrading existing Divisions into Sections. We have identified at least six to eight potential locations to form new Divisions at places such as Jaipur, Ahmedabad, Sholapur, Delhi and Mumbai, all of which may have new members who can contribute to advancement of the mobility community. To coincide with increased membership, we know SAEINDIA must devise and plan more activities and programs to serve our professional members.

Efforts already are underway to initiate certification programs for students and young professionals and a concerted effort will be made to align our work with NSDC and ASDC to create a strong foundation in the Skill India Initiative under the Automotive Board and Engineering Education Board. We also plan to organize programs on alternative fuels and energy conservation, environmental management and electric/hybrid Vehicles, among others, in important automotive hub locations. We also plan to step up activities under the Aerospace and Off-Highway verticals to build a vibrant ecosystem for our professional members, increasing the value of their SAEINDIA membership.

I am sure we will plan and execute the 2018 FISITA World Congress—India's first time hosting the event—in a world-class manner and style that will help elevate the banner of SAEINDIA on the global stage. We also are anxious to expand our activities and scale-up as many events as possible, while at the same time enhancing flagship events such BAJA, SUPRA, AWIM and the International Mobility Conference on a scale measurably higher than in the past.

I look forward to the continued support of each and every member of SAEINDIA. I'm pleased to receive feedback on our activities and suggestions for further SAEINDIA programs at my e-mail: **rkmalhotra@me.com**.

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SAEINDIA
News

KRT club inaugurations at Tafe and UCAL, April 2 and June 10, Chennai

Tractors and Farm Equipment Ltd., (TAFE) with a team of 50-plus SAEINDIA members, launched a Knowledge Round Table on April 2 at the TAFE premises. The program proceeded under the guidance of the SAEINDIA management committee, SAEISS Chairman Mr. Sriraman and TAFE vice-president, R&D and Mr. Sarangarajan, TAFE senior vice-president-operations.

The event also was attended by the SAEINDIA Southern Section Management Committee, Mr. S. Shanmugam, SAEISS vice chairman and Director–DDI, Dr. R. Rajendran, SAEISS MC and professor, **BSA University**, Mr. T. R. Sathyanarayanan, SAEISS treasurer and DGM-**WABCO**, Mr. B. Srinivasan, SAEISS MC and GM R&D, **UCAL** fuel systems. Mrs. Thangamalar, TAFE principal member (R&D) and KRT facilitator, managed the proceedings of the KRT.

Mr. S. Shanmugam gave a lecture on future competencies and Dr. R. Rajendran presented a lecture on surface engineering for the KRT members.

UCAL Fuel Systems Limited, with team of 21 members, launched KRT on June 10. The Knowledge Round Table was inaugurated in the presence of Mr. P. H. Narayanan, CEO, UCAL Fuel Systems Limited. Mr. B. Srinivasan, SAEISS MC and UCAL Fuel Systems GM R&D, took the initiative to form the KRT Club at UCAL. Dr. R. Rajendran gave a lecture on surface engineering of automotive components for the members at UCAL.

SAEISS chairman Mr. S. Sriraman addresses the audience.

SAEISS team on stage as Mrs. Thangamalar of Tafe addresses KRT members.

SAEINDIA Southern Section policy planning meeting, April 16-17, Chennai

SAEISS policy-planning team.

The SAEINDIA Southern Section conducted its Policy Establishment Meeting April 16-17 at **Ideal Resorts**, Mahabalipuram, Chennai under the leadership of Mr. S. Sriraman, chairman SAEISS. Most SAEISS management committee members participated and contributed to framing the new initiatives of the section.

Mr. S Selvamani, mentor for policy establishment, delivered a speech on society, governance, expectation and imperatives. Dr. E. Rajasekar, SAEISS secretary, presented the ongoing activities of 2015-16 and proposed activities, roles and responsibilities of the MC members for the 2016-17 period. Mr. T. Kasiraja, SAEISS joint treasurer, presented the 2016-17 budget.

Three new teams were formed to further develop the new initiatives identified and Mr. S. Shanmugam, SAEISS vice chairman, thanked all the members who attended the Policy Planning Meeting for donating their valuable time.

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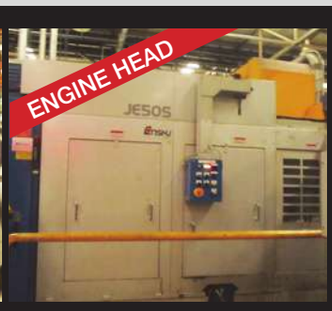

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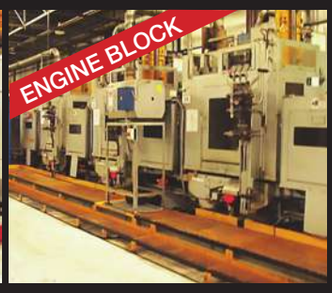

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SAEINDIA News

Lecture meeting, April 22, ARAI, Pune

The Eminent Speaker Series lecture on "Autonomous Cars: journey from passion to invention," was organized on 22nd April, 2016 at ARAI, Pune, and saw participation from engineers and scholars in engineering disciplines. The speaker for the lecture was Dr. Roshy John, Practice Head, Robotics and Cognitive Systems, **TCS**.

Dr. K.C. Vora, Vice President, SAEINDIA, welcomed the participants and introduced Dr. John, who earned his PhD in robotics from the **National Institute of Technology**, Tiruchirappalli, India. John has more than twelve years of experience in developing robots for different industries such as high-tech, consumer electronics, automotive, retail and banking. His major research interest is in robotics and automation that helps to remove humans from mundane and repetitive tasks—mostly in banking, retail and automotive environments.

He has been granted 16 patents in robotics, consumer electronics and software algorithms. Prior to TCS, Dr. John worked with **LG Electronics** as a senior scientist managing the consumer robot product research and development. He and his team recently built what in essence is a customizable autonomous-car kit. Although he hasn't built a car himself, he has managed the arguably even more daunting task of retrofitting a car with the hardware needed to drive itself.

Mr. Prakash V. Sardesai presented John with a memento as a token of appreciation.

Group photo of the lecture meeting.

Faculty internship professional-development training program, Chennai

In June, the SAEINDIA Southern Section, in association with **Siemens PLM**, organized a faculty internship professional development training program on three software topics: 1-dimensional model-based systems; plant-layout simulation and JACK simulation. SAEISS faculty members representing nearly 33 faculties took part in this program.

"1-dimensional model-based systems" was conducted on June 8 and 10 at **Siemens Software Ltd.** in Egmore. Mr. M. Murugadass Kannan of Siemens was the instructor and he explained how to control vibrations in hydraulic systems. During the valedictory session Mr. S. Shanmugam, SAEISS vice-chairman and Dr. R. Rajendran, Siemens training-program

Mr. Muragdass Kannan, Siemens, addresses SAE faculty members during F21 program.

Mr. S. Shanmugam, SAEISS vice chairman, presents participation certificate to a faculty member.


Mr. M. Sushil Jain of Siemens addresses the participants of the plant-layout session.


Mr. Aiyyappan Ramamurthi, Mr. T. Kasiraja and Mr. M. Amangarg present a certificate to an SAE faculty member.


Mr. B. Kumaran and Mr. M Sushil Jain present a certificate to a faculty member.


Mr. M. Amangarg of Siemens addresses the faculty members at the F21 program.

champion, distributed the certificate to the participants.

"Plant layout simulation" was conducted June 12 and 15 at Siemens Software Ltd. in Guindy and Mr. M. Sushil Jain of Siemens was the instructor. He explained how to organize the plant layout for a manufacturing arrangement. During the valedictory session Mr. B. Kumaran distributed the certificate to the participants.

"JACK simulation" was conducted June 15-17 at Siemens Software Ltd. in Guindy. Mr. M. Amangarg of Siemens was the instructor; he explained the various aspects of JACK simulation software and its use in the industry. During the valedictory session, Mr. T. Kasiraja, SAEISS joint treasurer and Mr. Aiyyappan Ramamurthi, member and vice-chair, distributed certificates to the participants and thanked all for attending.

All the instructors expressed their gratitude for the training program and also noted the effort undertaken by SAEISS and Siemens for organizing the training program.

Workshop for professional members, June 11, Bangalore

SAEINDIA Bangalore Section (BS) organized an exclusive workshop, "Know your car/how to handle when it breaks down," for its professional members on June 11 at **Navinith Motors BMW**. Chief trainer Mr. Munirathnam Dhananjayan (DJ), managing director, **Focus Engineering** and **BMW Group** certified after-sales consultant, led the workshop, which was attended by 40 professionals organized in morning and afternoon groups.


Mr. Javaji Munirathnam, SAEIBS chairman, speaks during the event.


Mr. Dhananjayan Munirathnam, Focus Engineering MD, attends the event.

The session was carried out with splendid display of various BMW models, followed by a theory session. The key highlight was on the next generation of hybrid car, BMW's i8.

The key MC members who led this successful event were Mr. Munirathnam Dhananjayan (DJ), Mr. Munirathnam Javaji, chairman SAEINDIA BS and SAEINDIA BS official Mr. Purushotham S. Joshi provided overall coordination.

SAEINDIA
News

SAENIS Efficycle 2016 June Workshops in New Delhi, Banglore and Pune

Team SAENIS Efficycle 2016.

SAEINDIA Northern Section (SAENIS) in association with **Maruti Suzuki** (MSIL) and the **International Centre for Automotive Technology** (ICAT) organized one-day workshops for the participants of the Efficycle 2016 event at three different locations in country.

These one-day workshops were organized at **Northern India Engineering College** (NIEC), New Delhi on June 18 for the teams from the north and east, at **Bangalore Institute of Technology** (BIT), Bangalore on June 19 for the teams from the south and at the **College of Engineering**, Pune, on June 26 for the teams from the west.

Workshops started with the formal inauguration, followed by a welcome speech from Shri U. D. Bhangale, senior general manager, **ICAT** and Efficycle 2016 convener. Workshops were delivered by the speakers from the Technical Committee, Mr. Jitendra Singh Gaur & Mr. Harpreet Singh Juneja of ICAT. Of the four sessions of the workshop, in the first two sessions teams were detailed regarding the rules to design and fabricate the vehicle. This year's event theme is "Build-Quality Season," so during the workshop, emphasis was given to the theme, focusing during the main event on good build quality for the vehicles. The first two sessions concluded with questions from teams, followed by lunch.

Mr. Jitendra Singh Gaur, technical committee, during SAENIS Efficycle2016.

The third session focused on the explanation of report formats the teams must submit at different stages of the event. During fourth and final session, teams were informed about the procedure of the main event, scheduled for October at **Lovely Professional University**. Elaboration of technical assessment at the college level, on-site technical inspection, the static events (design, cost, build-quality evaluation and marketing presentation round) and dynamic events (acceleration, gradient, maneuverability, utility and endurance run) helped the teams to understand the total evaluation process. Open sessions at the end of the program permitted teams to present questions to the speakers. Efficycle alumni members also shared their experience with the teams, about 120 of which, from all over India, attended the workshops in three locations.

Organizing committee members, Mr. Anubhav Singla, Mr. Rajkumar Dwiedi, Mr. Sumit Kumar and Mr. Akhsay Singla from **MSIL** and Mr. Utkarsh Tyagi and Mr. Udit Kaul from ICAT also were present during the workshops. Alumni Committee members Mr. Prateek Bansal, Mr. Ajinkya Shah and Ms. Charul Chaddha supported the organizing committee in successful conduct of workshops.

The workshop ended with the national anthem and the vote of thanks to host institutes.

Maiden flight of first Su-30 MKI with BrahMos missile achieved

The first flight of an Su-30 MKI aircraft with a **BrahMos** missile was successfully achieved at **Hindustan Aeronautics Limited** (HAL) Airport, Nashik in late June.

Sudhir Kumar Mishra, CEO and Managing Director, **BrahMos Aerospace Pvt. Ltd.** (BAPL), explained it is the first time in the world that such a heavy weight (2500 kg) supersonic cruise missile has been integrated on fighter aircraft.

A contract signed in 2014 between Hindustan Aeronautics Limited (HAL) and BrahMos Aerospace Pvt Ltd (BAPL) allowed for modification of two Su-30 MKI aircraft for integration of the BrahMos missile. First carriage flight was successfully achieved in late June 2016.

"It is an engineering marvel in aviation history of India. It proves that when all agencies come together with one mission, there is nothing like impossible," said T. Suvarna Raju, Chairman and Managing Director, HAL.

Raju noted that this program was taken on by HAL as an indigenous challenge by its Nashik Division and the required data was generated without the assistance of an OEM for the modification. It is not the techno-economics of the project, but HAL's commitment to self-reliance that drove HAL to sign the contract with BAPL in 2014 for modification of two Su-30 MKI aircraft for integration of the BrahMos missile, according to HAL. The first modified aircraft was airborne in one year and the second aircraft in the second year. This is the second project where HAL assumed the role of OEM and modified the airframe of license-built aircraft.

T. Suvarna Raju, CMD of Hindustan Aeronautics Limited, addressed the crowd at HAL-Nashik Airport after the maiden flight of the first Su-30 MKI with BrahMos Missile on June 25, 2016. The aircraft is in the background.

With the successful integration of BrahMos on Su-30 MKI, the aircraft has become a lethal weapon delivery platform for the **Indian Air Force**. Around 40 Su-30 MKI aircraft are expected to be modified. The maiden flight will be followed by series of test flights and complete evaluation and certification of the BrahMos missile on Su30 MKI aircraft, according to Raju.

The missile is developed by BAPL. Other agencies involved in the project include **CEMILAC** and **DGAQA**.

Bosch's connectivity platform tailored to Indian market

Bosch has developed a comprehensive connectivity platform that can reduce a vehicle's fuel consumption, foresee when maintenance is needed and display all information on the owner's smartphone.

In line with its "in-the-region-for-the-region" strategy, Bosch presented its Intelligent Transport Management System (iTraMS) at the Bosch Technology Exposition 2016 in Noida, India. Features of the system include tracking of vehicle location, condition monitoring and performance analysis. The flexible new Bosch solution works in passenger cars, commercial vehicles and off-highway vehicles. The iTraMS system is not only available in newly produced cars, but also as a retrofit solution.

"Bosch's iTraMS platform is a connectivity solution tailored to the Indian market. It provides accurate vehicle information on your smartphone and can immensely reduce everyday driving cost," said Bosch board of management member Dr. Markus Heyn, stressing the importance of local development. In addition, the key benefits of this platform include fleet management, essential and emergency services, off-road applications and intelligent transport solutions as part of smart-city solutions.

The Intelligent Transport Management System (iTraMS) from Bosch features tracking of vehicle location, condition monitoring and performance analysis and works in passenger cars, commercial vehicles and off-highway vehicles.

Another local development is Bosch's "e-Call," which was developed with contributions from the Bosch India engineering team. According to Bosch, e-Call resonates with the company's "Invented for life" ethos. Vehicles equipped with the safety system trigger an automated emergency call whenever a crash happens. Using data-mining techniques, the solution considers variables such as real-time vehicle, accident and environment information to estimate the probability of severe injury.

Bosch's mySPIN is a smartphone integration solution that creates a device-vehicle link to ensure safe and reliable on-board use. It allows occupants to continue using their preferred apps on their iOS or Android smartphones in the usual way, without having to compromise safety. mySPIN also

facilitates continuous access to online music services, social networks and a wide range of smartphone apps. By making it available for as many vehicles as possible, Bosch said it is helping to speed up the transition to safer and more ecological driving.

Mahindra launches e2o ElectriCity Car in the UK

Mahindra recently made its entry into the UK automotive market with the launch of the e2o electric city car. Designed specifically for easy urban commuting, the Mahindra e2o features several connected technologies and will be available in two trim levels. The entry-level e2o City is priced competitively, according to Mahindra, while the higher-spec TechX version includes a touchscreen infotainment center with reversing camera, telematics, revive remote emergency recharging, leather seats, alloy wheels and a rapid charging port.

Anand Mahindra, Chairman of the Mahindra Group, with the new e2o in London where the company announced its entry into the UK automotive market with the electric city car.

Speaking about the e2o's arrival on British roads, Anand Mahindra, Chairman, Mahindra Group said, "I am very proud to announce that the e2o is now available in the UK and this marks a true milestone for the Mahindra Group. Sustainability is at the heart of Mahindra's business practices and with the introduction of the e2o to the UK market, we are offering a product that perfectly encapsulates our corporate philosophy."

At the core of the e2o is a collection of connected features that were developed to make the car both easier and more enjoyable to drive and maintain: e2o Remote smartphone app allows users to remotely control key functions of their e2o, including the ability to preheat/cool the car, start and stop charging, route plan and search for nearby charging stations; Remote Charging Scheduler is an app that allows users to schedule charging of their e2o at a time when electricity rates are at their cheapest; Revive is a remote emergency-charging feature to enables battery reserve for up to 8 mi (13 km) worth of range if the battery is depleted, while telematics onboard sensors send a data "heartbeat" to Mahindra, enabling remote health monitoring and customer alerts.

The Mahindra UK website http://www.mahindrauk.com is live and ready to take orders; first deliveries to UK owners were slated to begin in May 2016.

Blaupunkt renews license agreement for infotainment solutions in India

Car infotainment and audio accessory supplier **Blaupunkt** has renewed its license agreement for the brand in India. The agreement has been signed between brand holder **Global Intellectual Property Development** and **Blaupunkt India** Pvt. Ltd. for a tenure of five years, with an option of another five-year extension. Blaupunkt India will continue to offer and add to the portfolio of car infotainment products and accessories under the brand's umbrella. Offering consumers an enhanced driving and in-car experience, Blaupunkt's range of products include car audio systems, speakers and amplifiers, Bluetooth connectivity products, driver assistance systems, rear-seat entertainment, car fresheners and purifiers among other related offerings.

According to the company, for the next five years Blaupunkt India will focus on being one of the top three companies in the car infotainment business in India as well as be the brand of choice for OEMs for the genuine accessory business and their preferred choice for limited-edition models.

Blaupunkt India will add to its portfolio of car infotainment products and accessories. The Cape Town 940 Android-based Blaupunkt user interface features a 6.8-in capacitive display and combines high-quality tuner performance, regional navigation options and a variety of different entertainment features.

"We are glad to extend the business relationship for Blaupunkt car infotainment business in India," said Pankaj Jagwani, Director, Blaupunkt India, "Our strong belief lies in the brand's core values of quality, innovation, strength, longevity and reliability which is the cornerstone of German engineering, through which we have established the brand in the Indian market through numerous launch events and promotional activities...The plan ahead is to maximize customer experience and further expand our footprint with the existing range and exciting new product launches."

According to Andrzej Cebrat, Managing Director, Global Intellectual Property Development, "We have had a successful partnership with Blaupunkt India over the years and are pleased to continue our association. India is a lucrative market and presents great opportunities for the brand, which has been well received and risen as a leading car infotainment brand among the country's consumers. We are confident this is going to be a productive partnership and are looking forward to the exciting plans and product launches planned by Blaupunkt India."

AUTOMOTIVE POWERTRAINS

OEMs expand testing of FEV variable-compression ratio engine

Dean Tomazic, FEV North America CTO, with a mock-up demonstration engine featuring the company's 2-stage VCR technology. (Lindsay Brooke photo)

Centerpiece of FEV's 2-stage VCR system is its cleverly-engineered eccentric connecting rod, shown here in the company's demo mock-up. (Lindsay Brooke photo)

Road testing of a new variable-compression ratio (VCR) combustion system in Europe has been "very successful to date" as OEMs validate the **FEV**-developed technology, reports Dean Tomazic, Executive Vice President and CTO of FEV North America.

"We're working with several customers and there are more to follow. We've been conducting test-fleet operations for many months," with 50 engines in use, Tomazic told *Automotive Engineering*.

He described FEV's 2-step VCR, which offers a 3-5% increase in fuel efficiency, as "a relatively big 'hammer' to employ for CO_2 reduction. It can significantly extend the operating window, allowing you to operate at higher power levels without incurring (engine) knock."

With the expanding European test program, the VCR technology is "gaining momentum" toward productionization, with FEV in discussions with potential Tier 1s, Tomazic noted. The modular technology can be adopted as a clean-sheet or retrofit for diesel, gasoline, flex-fuel engines in any cylinder configuration.

FEV has been in the vanguard of VCR design, development and testing since the 1990s. In 2009 the company published an **SAE** technical paper (http://papers.sae.org/2009-01-1457/) describing the 2-stage VCR system now under test by OEMs. The mechanical centerpiece is a clever adjustable-length connecting rod featuring a rotating eccentric eye within the rod's "little end."

"It's a simple, passive system, requiring just a bit of hydraulics and a 2-way valve to lock the system into positions 'A' and 'B,'" Tomazic explained. The con rod's unique design incorporates two small hydraulic pistons, each within a dedicated chamber; the hydraulics in the two small cylinders serve only as a locking function to stabilize the mechanism in the 'A' position.

"We basically drain one chamber and make the other one accessible to low-pressure oil that comes through the crankshaft and the con rod into that chamber," Tomazic said. The chamber fills up and the oil flows back through a check valve. The primary (large) piston is moved up and down relative to the rod exclusively by the mass and inertial forces.

Transitioning from compression ratio 'A' to 'B' is achieved within 0.2 to 0.6 s. According to Tomazic, a typical ratio change in a gasoline engine would be from 11:1 to 15:1. The piston's maximum vertical lift threshold of 1.5 to 2 mm (.06 to .07 in) is adjusted in real time according to load and available fuel quality, via inputs from knock and fuel-octane sensors.

FEV engineers have evolved the VCR using one of the company's proprietary analysis toolsets known as CMD (Charge Motion Design), based on optimized CFD. Compared with fixed-ratio and full-variable compression-ratio designs, the 2-stage VCR enables higher potential fuel economy in spark-ignited ICEs, particularly as average peak firing pressures (up to 170 bar/2466 psi) increase.

Some powertrain engineers have commented that even with the presumed cost benefit of mass production, FEV's sophisticated con rod would be many times more expensive per unit than a current-production conventional steel rod. Tomazic argues that the greater complexity is part of the industry's investment in advanced ICE technologies to meet the next phase of CO_2 regulations.

"It's getting more expensive to reduce emissions and improve fuel economy," he noted. "OEs are weighing variable-compression-ratio engines versus electrification. They're finding 2-step VCR is very cost competitive, whereas five years ago it wasn't—because there was lower-hanging, lower-cost fruit available to meet their targets."

Lindsay Brooke

OFF-HIGHWAY ELECTRONICS | POWERTRAIN

Automation, electrification focus of ZF's Innovation Tractor prototype

Traction management on the ZF Innovation Tractor enables vehicles to start on uphill gradients of up to 30%, thanks to electrically powered wheel heads installed on the trailer that provide additional drive torque.

The passenger-car industry may be driving development of advanced driver-assistance systems (ADAS) and electrification, but the off-highway segment may be best-positioned to utilize them more widely—and sooner.

"The main movement for [driver-assistance systems] is in passenger cars, although it's much more difficult to get this on cars because of all the regulations," said Dr. Manuel Götz, responsible for Advanced Engineering, Industrial Technology at **ZF**. "So I believe in the future, we'll be seeing autonomous vehicles in off-highway more regularly and even earlier than on the highway. Due to the fact that we're in an enclosed environment and don't have the regulations of on-highway, this could make things easier to implement."

"A higher degree of automation also addresses the trend of operators being less trained in the future and not being able to find highly trained people to operate more and more complex machinery. So this [Innovation Tractor] is a step toward autonomous operation," he added.

ZF is making a concerted effort to transfer the intelligent systems it's developed initially for passenger cars into heavy trucks and buses, as well as off-highway equipment. To effectively illustrate this point, engineers in the company's Advanced Engineering department have spent the past year designing the Innovation Tractor, an advanced-technology demonstrator loaded with cameras and electronics to allow automated maneuvering and hitching, not to mention pedestrian detection. Electric single-wheel drive for trailers and implements helps to dramatically improve traction management, as demonstrated in Aachen, Germany, on a 30%-grade paved road that was thoroughly watered down.

"We have full control not only of the driveline and the engine on this vehicle but also the steering and the brakes," he said. "This is necessary to have full control over the vehicle and to do things like trajectory control and steering the vehicle."

Agricultural was selected as the first application for these automation technologies, but they are viable for construction and other off-highway segments, said Götz.

"The Innovation Tractor brings together in a test prototype all the new functions we believe are practical for agricultural and construction applications," said Dr. Harald Naunheimer, Head of R&D at ZF Friedrichshafen AG. "The focus was on demonstrating what is already possible and technically feasible today, but sets a benchmark on future innovation."

Automated operation and hitch detection

The Innovation Tractor is equipped with 10 environmental cameras to monitor its surroundings; the data from these cameras enables the vehicle to maneuver semi-autonomously or via mobile devices operated outside the driver's cab, making it easier to hitch implements, for example.

Six cameras are mounted on the driver's cab and the hood. A computer analyzes the images and generates a 360° surround-view image of the tractor's environment. The operator can view this image on a tablet from various perspectives, including a bird's-eye view.

These cameras could be linked to provide warnings for obstacle detection and to brake, if necessary, as is becoming more common in passenger cars, Götz said.

Two cameras located at the rear of the tractor are used for the Hitch Detection function. Two additional rear cameras, monitoring a 180° swath, have pedestrian-detection capabilities. These four rear-mounted cameras have a separate data-processing unit.

In future iterations, the tractor ideally will utilize just four cameras, all mounted on the roof, to handle all of these functions, said Götz.

The Innovation Tractor's SafeRange

The Hitch Detection system allows the ZF Innovation Tractor to automatically approach implements to within 1.5 cm (0.6 in) so they can be easily hitched.

Pedestrian Detection ensures the ZF Innovation Tractor stops automatically whenever someone gets in the way.

function allows the driver to leave the vehicle and remotely control the tractor/trailer combination from a safe distance. The Innovation Tractor and trailer are outlined as a bird's-eye view on a tablet display from which all the relevant driving and steering commands are managed. Dragging the tractor or trailer image with a finger to the right or left on the screen causes the actual tractor/trailer combination to maneuver in the chosen direction. For reversing in complicated situations, the user can specify the desired direction for the trailer and the system calculates and executes all the necessary steering movements.

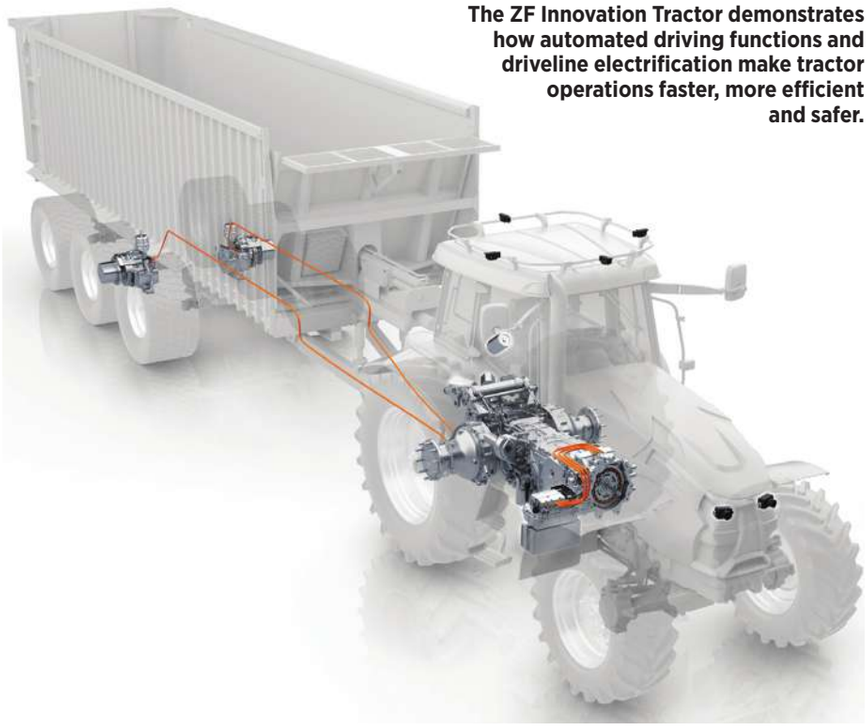
Speed is set by swiping the screen from the center to the edge, across the tractor model or the trailer. The maximum forward speed is 4 km/h (2.5 mph), with the top reversing speed limited to 2 km/h (1.2 mph). When contact with the screen is interrupted, or if radio contact is lost between the tablet and the tractor, the vehicle stops automatically.

SafeRange also works when maneuvering the tractor without a trailer.

For the automatic hitching, currently there are three target shields mounted on the trailer to help guide the system. These shields will eventually go away, said Götz, but additional technology is required for that to happen.

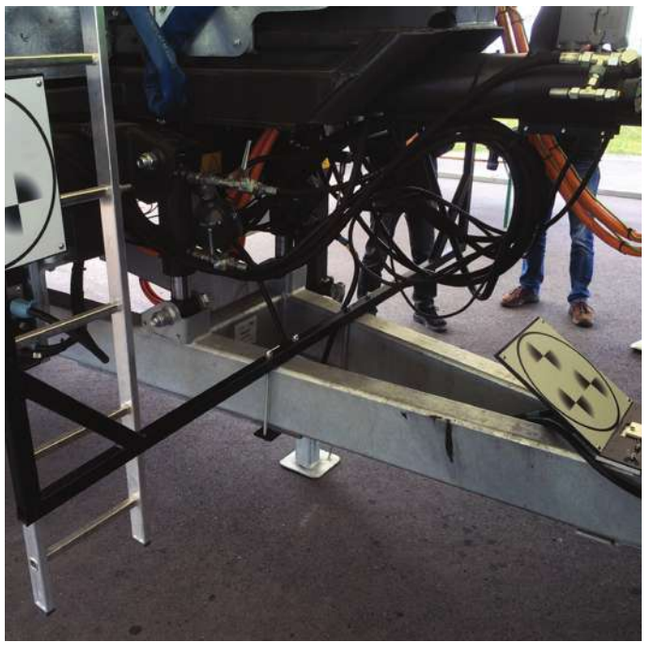
"You have the opportunity to train your algorithm better on different implements, but this is a very lengthy [process]. I believe that in the future we might have a system that combines an optical camera and a laser system. With laser you have additional possibilities of detecting much more accurately, not only distances but also how the environment is changing. So I think we'll see this sensor fusion for autonomous operation," Götz explained.

The Hitch Detection system uses cameras to detect the exact position and angle of the trailer in relation to the tractor by using the targets. It works up to a distance of 7 m (23 ft). The position is continuously measured during the hitching process and the angle of the steered wheels corrected. The Innovation Tractor maneuvers automatically until it reaches the optimum position for hitching, which then is completed by hand. The system has a tolerance of 1.5 cm (0.6 in).



The ZF Innovation Tractor demonstrates how automated driving functions and driveline electrification make tractor operations faster, more efficient and safer.

Dr. Manuel Götz of ZF's Advanced Engineering for Industrial Technology believes autonomous vehicles will flourish in the off-highway realm earlier than on the highway due to the structured environments and fewer regulations. Behind him are the four cameras used for hitch and pedestrian detection. (Photo by Ryan Gehm)



For automatic hitching, currently there are three target shields mounted on the trailer to help guide the system. In the future, the system could use sensor fusion that combines an optical camera and a laser system to eliminate the need for shields. (Photo by Ryan Gehm)

While using the tablet for maneuvering and hitching, cameras can detect pedestrians located between the vehicle and trailer up to 7 m away, with this information also displayed on the tablet. If the person controlling the tractor fails to respond, the system stops the vehicle. The interrupted hitching process can be restarted only once the pedestrian has moved out of the way.

"Many accidents happen on the farm with people getting run over, so this is a huge step," said Götz. "Right now, we don't have the regulations demanding such a solution, but once the industry shows such technology I believe there will be regulations to have it implemented on the vehicles."

Driveline electrification

Drivetrain electrification for the Innovation Tractor comes via ZF's TERRAMATIC transmission with the TERRA+ generator module, an electric single-wheel drive for trailers and implements, coupled with specially developed traction management. An electric steering system, required for automatic-driving functions, has been built into the control network.

This system generation can provide 50 kW of continuous electrical power and serves as the power source for the electrical consumers in the trailer. Two liquid-cooled, 3-phase asynchronous motors are integrated into the electrical wheel heads, saving space on the trailer axle; for the Innovation Tractor's trailer, the system was installed on the middle axle. The nominal voltage is 400 V, and the system also can be fitted with a wheel brake.

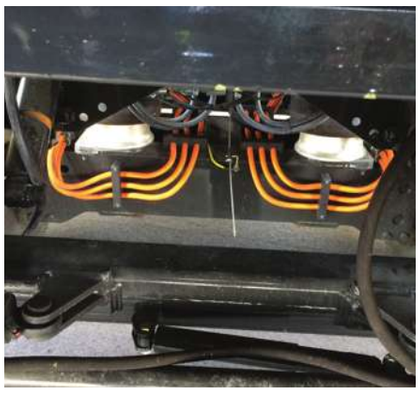
The motors provide 6000 N·m (4425 lb·ft) maximum torque to each wheel.

"We have not yet implemented [the braking] but it is possible; it will be our next step," said Götz. This function can help with deceleration when going downhill or making a turn, helping to prevent jackknifing and rollover. "We have to implement it in the control so we can use the electric axle to provide a braking torque. It is just a matter of applying the parameters."

Torque vectoring—which is employed in automotive differentials and provides the ability to vary the power to each wheel—is another technology currently not available on the tractor but would be possible to implement, he said.

"From a space perspective we can go up to 70, even 100 kW continuous power," said Götz. "In the vehicle at the moment we have installed a 50-kW generator system which is linked to our power electronics, from which we transfer the electric current to the wheels of the trailer. We're not only powering them, we're also controlling

For serial production, packaging of the electric drive components will be more of a focus. On the prototype tractor, externally mounted metal enclosures house the inverters. (Photo by Ryan Gehm)



Two liquid-cooled, 3-phase asynchronous motors are integrated into the electrical wheel heads, saving space on the trailer axle; for the Innovation Tractor's trailer, the system was installed on the middle axle. Orange wire harnesses are the only visual indicator of the electric setup. (Photo by Ryan Gehm)

them; this way we are able to realize optimized traction control between the tractor and the trailer."

The all-wheel-drive function of the ZF tractor and the electrical-boost function from the single-wheel drive on the trailer combine to deliver optimum traction management. With electrical assistance from the trailer, the tractor can climb uphill gradients of up to 30%, terrain normally off-limits for a conventional tractor/trailer setup, Götz noted. It also helps in difficult conditions in the open field.

A combination of two inputs determine traction management: the coupling force to determine if the trailer is pushing or pulling, and detection of load in the trailer.

The additional power from the trailer also allows a higher payload to be transported with a downsized tractor, ideal for users who only occasionally tow a fully-laden trailer.

ZF admits that its current CVTs are about as efficient as the full electric drive and less costly, so that hinders the move toward electrification. Other factors, however, such as improved controllability and the possibility for optimized traction control can help spur electric-drive adoption. As, of course, could CO_2-emissions regulations, which "might not be that far off" for the off-highway sector, somewhere between five and 20 years down the road, Götz predicted.

Ryan Gehm

TRUCK POWERTRAIN

Unique piston design aids HD diesel waste heat recovery

Federal-Mogul will show its new Envirokool piston at the IAA Commercial Vehicles Show in Hanover in September. It's designed to withstand higher temperatures by incorporating a sealed-for-life cooling chamber within the piston crown. The chamber is filled with a specifically formulated cooling oil and an inert gas. The cooling gallery is integrated in the steel piston using friction welding and after charging with the oil and gas is permanently sealed with a welded plug. The inert gas ensures that the coolant will not oxidize.

As a result, the piston crown can withstand temperatures more than 100°C (180°F) higher than possible today. By running at higher temperatures, it would ensure that carbon deposits that would normally form in the cooling gallery would be burnt off, in turn ensuring that heat could be dissipated for the life of the piston.

Heat is transferred from the undercrown through the piston pin, skirt and ring pack and also by using a standard engine oil cooling jet. Since Federal-Mogul claims the Envirokool technology is so effective, the oil cooling flow to the spray jet can be reduced by 50%, which would reduce the workload on the engine oil pump, reducing parasitic losses as well as decoupling the engine oil from cooling, to an extent.

"The technology is mainly applicable to engines with waste heat recovery," explained Norbert Schneider, Director Global Application Engineering at Federal-Mogul. "Because just making a piston hotter doesn't save fuel. Right now, the piston is cooled tremendously with lubrication oil. All that heat energy is going into the radiator and is totally wasted. The idea is to increase the temperature of the exhaust gas by cooling the piston much less, but then the piston gets hotter, which is why we need this technology and then with the much hotter gases, a significant proportion of this waste heat can be recovered."

Up to 5% of energy can be recovered in current waste heat recovery systems and fed back into the drivetrain. "Future legislation will demand a significant reduction in fuel consumption for

Federal-Mogul's Envirokool piston incorporates a sealed-for-life cooling gallery under the piston crown.

trucks, engines, and right now this is seen as having a very important potential," said Schneider.

Raising the temperature of exhaust gases will mean that emissions of oxides of nitrogen (NOx) will be increased. "The engine companies would have to optimize their whole combustion and they would have to investigate how much selective catalytic reduction (SCR) they use, or whether they would use exhaust gas recirculation (EGR). The emissions will still need to be compliant. This would change the combustion significantly.

"It will be several years before we could expect Envirokool to go into production. This is a relatively early stage. We have already been carrying out testing for two years with more than a thousand hours of successful results, and we are now in a pre-development stage with a small number of engine companies. We would expect mass production to begin from 2021."

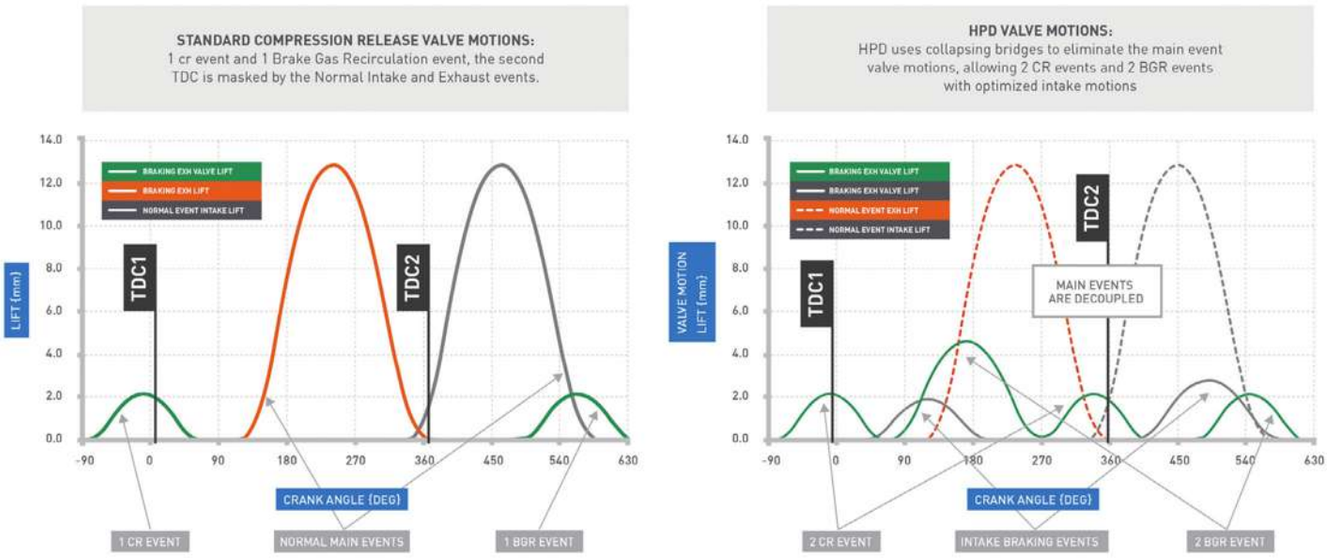
The technology could be applied to both vehicle engines and stationary engines. Schneider told *Off-Highway Engineering* that the best results would be achieved from engines covering long distances or running for long hours.

John Kendall

TRUCK POWERTRAIN

Two-stroke future for heavy-duty engine braking

HOW HPD WORKS



Graphic comparison between regular compression release brake and HPD shows additional braking events.

It typically is rare that the driver of a heavy truck or bus loses control of the vehicle because of brake failure caused by overheating the foundation brakes. This is partly because of the widespread use of auxiliary braking systems, which use equipment other than the foundation brakes to reduce speed, particularly on long downhill grades.

The compression release brake provides an alternative to traditional exhaust brakes and retarders, with a design pioneered by U.S.-based **Jacobs Vehicle Systems** in the 1960s. Conventionally, it takes the backpressure retardation principal a step further by controlling the exhaust valve opening on the exhaust stroke to create compression and therefore resistance to motion rather than the usual scavenging. Since the fuel supply is turned off when there is no demand for fuel in a modern diesel engine, there is no interference with the normal functioning of the engine. The exhaust valve remains closed until top dead center.

Jacobs' HPD compression release engine brake adds intake valves and turbo boost control to hike efficiency.

The effect is produced by installing a bridge under the cam follower. This contains a control solenoid valve that meters the flow of oil to a hydraulic actuator, which acts on the cam instead of the regular cam follower. The oil supply is drawn through a drilling in the rocker shaft. Under power, the solenoid valve is closed and the actuator piston is locked to the bridge enabling the valve to follow the cam profile for four-stroke operation. When braking is required, the solenoid valve is opened, unlocking the actuator from the bridge and causing the valve to remain closed until top dead center is reached. Since the cam profile of the engine remains the same and the bridge cannot extend valve lift or timing, the brake does not pose a threat to the integrity of the engine.

It follows that larger-capacity engines offer the potential for more retardation, but the trend in recent years has been toward engine downsizing, which has had the effect of reducing engine braking potential. At the same time, rolling resistance has been reduced by the introduction of more aerodynamic vehicle designs, low rolling resistance tires, and reduced driveline friction. In other words, there is less built-in resistance to motion in a modern heavy vehicle. At the same time, gross vehicle weights for heavy trucks have increased since the 1990s in regions such as Europe, with maximum permissible weight reaching 44-tonnes for regular use in the European Union.

Jacobs' data suggests that continuous improvements in engine design and engine-brake design have helped to raise compression-release engine braking from around 8.0 kW/L at 1500 rpm from a 1960s heavy diesel with mechanical fuel injection to 20 kW/L at 1500 rpm by the late 1990s, when

engines had adopted dual-camshaft designs and the engine brake had been integrated into the valve train with a dedicated cam.

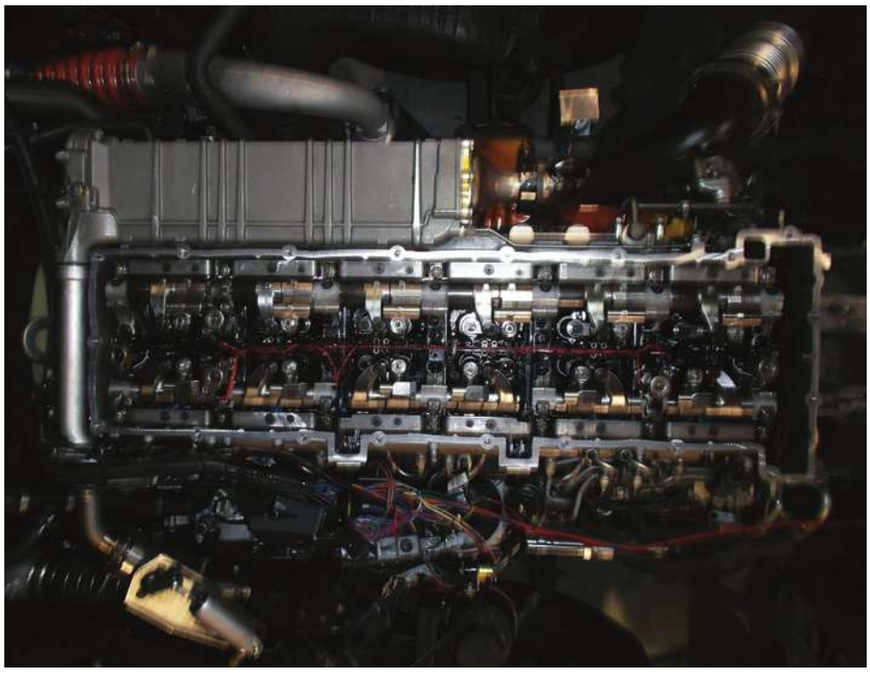
High Power Density engine brake

Despite the greater efficiencies of engine brake designs, increasing gross weights, lower rolling resistance, and engine downsizing have driven the need for more auxiliary braking power. Jacobs response is the High Power Density (HPD) engine brake.

With HPD, the same system of bridge, control valve, and hydraulic actuator is applied to the inlet cam as well. This enables the engine to switch from four-stroke operation under power to two-stroke operation under braking, thereby doubling the number of "braking" strokes. At the same time Jacobs is able to use boost from the turbocharger more effectively by controlling it to optimize boost charging for braking.

"You need to look at this as a system of how we control the valves on the intake, the exhaust, and the turbocharger," explained Tom Howell, Director of New Technology at Jacobs Vehicle Systems. "All these components need to be considered. By having two intake events, it enables us to get a larger amount of airflow through the engine and by having two compression release events, that's obviously utilizing the air that's provided by the two intake events."

The result has been to increase the available braking power to around 28 kW/L at 1500 rpm, with a maximum of around 37 kW/L at 2200 rpm. Jacobs claims one and a half times the braking performance of a traditional compression release brake over the engine's operating range with the same retardation at 1400 rpm as at 2100 rpm with the previous system. For a 13-L engine, Jacobs claims 2000 N·m (1475 lb·ft) of retarding torque at 1300 rpm and above with 611 kW (819 hp) of braking power at 2500 rpm.



Installed system on inline six-cylinder engine shows components on exhaust and intake valve gear.

As fitted to the **Mercedes-Benz** Actros demonstration vehicle, Jacobs claims braking power of around 370 kW (495 hp) at 1500 rpm. Jacobs says that the total system weight is around 12 kg (26 lb) compared with 150 kg (330 lb) for a hydraulic retarder. All additional heat is expelled through the exhaust system, helping to keep diesel particulate filters at working temperature.

Jacobs provided two identical Actros models loaded to 40-tonnes gross combination weight for demonstration, fitted with 13-L inline six-cylinder engines. One was equipped with the conventional compression-release brake and the other with the HPD system. Demonstration drives took place on the Hill Route at the **Millbrook Proving Ground** in the U.K., not normally open to laden trucks because of the 26% steep descent on one section.

While we were able to control descent on the 26% gradient in the vehicle equipped with the conventional system, additional check braking using the foundation brakes was needed. The HPD-equipped vehicle gave far greater control and with HPD engaged early enough, it enabled descent without using the foundation brakes, notable on such a steep descent.

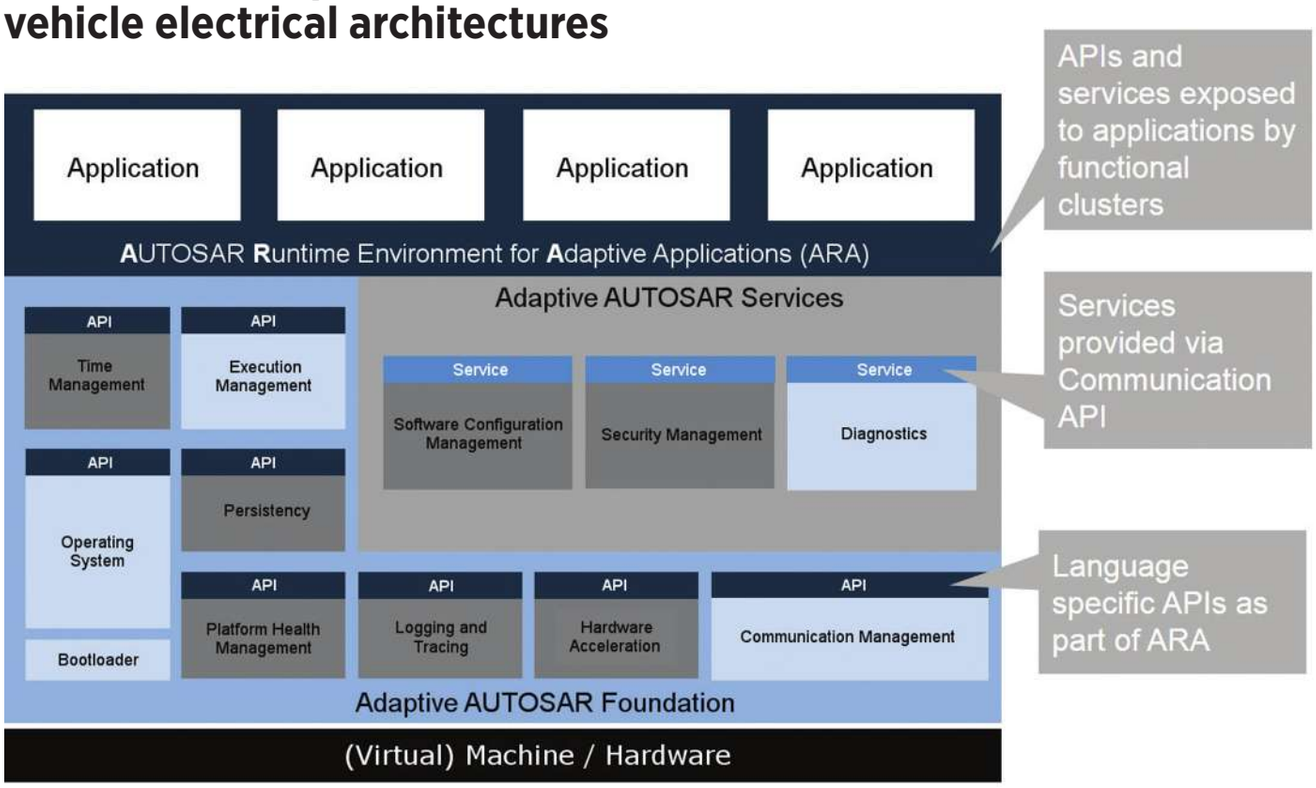
The HPD-equipped vehicle was equipped with a potentiometer to control the turbocharger boost because it provided too much retardation on lesser grades. This could take the form of a four or five position column stalk on an OE-integrated installation.

John Kendall

Test track demonstration showed the performance differences between trucks equipped with Jacobs regular and HPD compression brake systems on a 26% gradient.

AUTOMOTIVE ELECTRONICS

New AUTOSAR platform: more freedom for vehicle electrical architectures



Set to debut in 2017, AUTOSAR Adaptive makes it easier for a range of different application programming interfaces (API) and modules to communicate randomly.

Because they require controllers that communicate with each other more randomly than the fairly dedicated links between current-day modules, advanced-safety, connectivity and autonomous features are altering vehicle electronic architectures. That's prompted the Automotive Open System Architecture (**AUTOSAR**) development partnership to devise a new standard that adapts to changeable communication patterns.

The AUTOSAR Adaptive Platform, currently targeted for completion in 2017, is designed to help engineers create more flexible electrical architectures. AUTOSAR Adaptive will provide a software framework for more complex systems and help engineers increase bandwidth by implementing Ethernet.

In forthcoming architectures as diverse as infotainment and advanced driver assistance systems (ADAS), increased and faster communication will be necessary to provide features and functions that can't be handled by dedicated modules alone. The rapid proliferation of electronic controls and communications has fueled growing acceptance of AUTOSAR and the new upgrade augments existing deployment of the standard.

"It's important not to think of AUTOSAR Adaptive as a replacement for AUTOSAR," said Alexander Much, head of software systems engineering for car infrastructure at **Elektrobit**. "Currently, vehicles have very static architectures where brake and steering modules send a lot of messages to nodes that 'know' who and where all the units are," he said. "Now, more dynamic things are coming, where nodes don't need to know where computers they are communicating with are located or when they're going to transmit."

"AUTOSAR Adaptive will concentrate a bit more on ADAS needs in the short term," said Kurt Krueger, North American Product Line Director for Embedded Software at **Vector CANtech**. "Highly automated driving systems must be dependable and have fail-safe operational capabilities. This can only be accomplished with high-performance microcontrollers, computing power, and high data transfer rates."

Designed to meet key requirements with regard to autonomous driving, the AUTOSAR Adaptive Platform comes with features such as high data processing capacities, service-oriented communication and updates over the air, Rathgeber explained. He added that AUTOSAR strives to be a key enabler on the way to the self-driving car by making the new platform accessible to as many manufacturers, suppliers and developers as possible.

Among the development committee's goals is to create a dynamic system that includes middleware and supports complex operating systems using a Posix interface and multicore microprocessors. Its main communication approach is based on service-oriented communication and IP/Ethernet.

The platform will be capable of supporting adaptive software deployment while interacting with non-AUTOSAR systems.

Terry Costlow

AEROSPACE AVIONICS

Northrop Grumman navigates on the Neuron UCAV demonstrator

The Neuron is the first large-size stealth platform to be designed in Europe.

Neuron is an experimental UCAV developed with international cooperation, led by France, and includes government and industry partners from Greece, Italy, Spain, Sweden, and Switzerland.

Northrop Grumman's subsidiary in Germany, Northrop Grumman LITEF, teamed with **Saab Aerosystems** to provide the AHRS (attitude and heading reference system) for the Neuron unmanned combat air vehicle (UCAV) demonstrator, which recently conducted more than 100 test flights in France, Italy, and Sweden.

Neuron is the first large-size stealth platform to be designed in Europe. The program aims to develop, test and sustain key technologies for use by European manufacturers in the next generation of unmanned aerial vehicles and combat aircraft.

The fiber-optic, gyro-compassing LCR-100 AHRS for the UCAV demonstrator is Technical Standard Order/European Technical Standard Order (TSO/ETSO) certified and was developed according to DO-178 and DO-254 standards.

The LCR-100 is one of the key components of the sensors suite of Neuron used for navigation and flight guidance and control. The LCR-100 provides primary flight control information to the aircraft's flight control system, as well as hybrid inertial and Global Navigation Satellite System (GNSS) navigation information through a separate GNSS unit.

Northrop Grumman says the weight, volume, and power consumption of this AHRS is about one-third of a comparable system fitted with mechanical gyros and is the culmination of over 10 years of research on fiber-optic gyros and MEMS (micro electromechanical systems. The LCR-100 provided the data in ARINC 429 format during all the Neuron flight test campaigns.

Dassault Aviation is the prime contractor for 10-m long, 12-m wide Neuron. Some of the specific technologies targeted by researchers relate to low signature (stealth) technology, flight testing, aerodynamics, avionics, fuel system, the critical part of the ground station, as well as the design and production of the main fuselage.

Jean L. Broge

AUTOMOTIVE INTERIORS

Bolt EV seat design cuts weight, delights taller passengers

Stepping into the back seat of **Chevrolet**'s 2017 Bolt EV, one attribute of the car is immediately evident: the designers and engineers didn't neglect the outsized physical dimensions of tall passengers.

In fact, even those whose height and inseam length are well beyond the 90th percentile—that would include the author—will appreciate the Bolt EV's surprisingly easy ingress and egress. That's because the car's front seats were designed with the back-seaters in mind, as well as being designed to reduce mass.

Bolt EV's front seats were designed in house by **GM**. They're known internally as UTSB—Ultra Thin Seatback. The seats are designed and engineered in combination with the similarly well-considered rear-seat system (both supplied by **Magna Seating**) to improve the interior spaciousness of a vehicle that feels larger inside than its compact exterior form would indicate. The front seats are engineered with a light steel seat frame over which a flexible plastic shell is fitted. The shell is lined with 0.4-0.6-in-thick (10-15 mm) foam.

Swing your torso and legs into the rear seat area, as *Automotive Engineering* did during a pre-production test drive last winter, and the Bolt's rear knee room feels extra special for a B-segment vehicle. The rear seat back still has a metal structure and includes a sculpted back panel to provide increased rear-seat leg room. Behind the fold-flat 60/40 rear seat, the Bolt offers 16.9 ft^3 of cargo space—more than the current B-segment leader in this metric, the 2016 **Honda** Fit.

GM-designed, Magna-supplied front seats in new Bolt EV are lightweight, save space and help mitigate occupant crash protection according to the car's Chief Engineer Josh Tavel. (Lindsay Brooke photo)

Magna's FutureForm concept seat boast a 20% mass saving versus comparable production seats, the company claims.

The front seats' backside fascias are molded with a concave surface geometry in their center so that taller backseat passengers are not always required to ask the driver and front-seat passenger to slide their seats forward. Pam Fletcher, GM's Executive Chief Engineer for Electrified Vehicles, explained that the Bolt EV "was designed with ride-sharing as a potential consideration." Think GM's investment in **Lyft**.

According to the Bolt's Chief Engineer, Josh Tavel, the UTSB front seats also are lighter overall than comparable GM seats as used for the Chevy Sonic, for example, but he was not yet prepared to reveal the exact mass delta. The front seats also incorporate the side airbag modules as a design element.

Magna Seating is responsible for the Bolt seats' foam and trim design. The company also handles complete assembly of the seats at its Detroit plant, which also produces seats for the Chevrolet Volt, the Bolt EV's plug-in hybrid cousin.

Magna has itself been a pioneer in developing lightweight, thin-profile seat designs. It first exhibited a thin-section lightweight (less than 22 lb/9.9 kg) vehicle seat in 2000, on GM's 80-mpg Precept hybrid concept car. The company's latest FutureForm concept is claimed to offer a 20% mass reduction versus comparable production seats, along with a nearly 2-in (50 mm) improvement in rear-seat passenger legroom, the company claims.

Lindsay Brooke

AUTOMOTIVE DESIGN | INTERIORS

Rolls-Royce reveals a Vision of its future

"When it doesn't exist, design it," was Sir Henry Royce's maxim aired some 100 years ago. Now it is being followed to the letter with the revealing in London of the **Rolls-Royce** Vision Next 100, an extraordinary concept that is a huge departure from anything that Sir Henry could possibly have envisaged.

It is a purely visionary concept from today's Rolls-Royce design and engineering teams indicating their views of what could become super-luxury mobility reality over the next 100 years. This ultra-time projection, created using extensive 3D printing, brings exterior aesthetics the like of which Rolls-Royce has never before dared to present. Fully autonomous technology obviates the need for a steering wheel, a driver's seat, and all instruments except an analog clock—itself a reminder to passengers that "time not lost is the highest form of luxury."

What potential customers will make of this project, code named 103EX, will probably be a dichotomy. Some will applaud the 5.9-m-long (19.3 ft), battery-electric Next 100's image and promise, and others might dismiss it—to borrow the phrase of British writer and poet John Betjeman—as showing "ghastly good taste."

Details of the far distant technology involved are necessarily nebulous. But Rolls-Royce expects the vehicle to be based on an advanced, hand-built, lightweight platform equipped with two high performance traction motors positioned front and rear producing some 500 kW (670 hp) combined, driving all four of the car's 28-in-high (711-mm) wheels. Everything from wheelbase to body design and the car's various specifications and equipment, could be tailored specifically to suit the needs of the individual customer.

Progress in composite materials and technologies is expected to provide the production capability to provide such levels of customization.

Rolls-Royce sees these vehicles as "unique masterpieces curated as a 'fingerprint' of their owner"—a description that could only come out of this brand. The interior becomes a "personal retreat." For trim, the designers have chosen a carpet of hand-twisted silk with "extraordinarily soft silk" for the upholstery.

If you fell asleep in 2016 and woke up 100 years hence to see this vehicle, you'd recognize it as a Rolls-Royce. The Vision Next 100 concept carries forward the marque's design language including the Spirit of Ecstasy mascot and iconic radiator grille.

No steering wheel, no instruments except a clock, no driving seat, just a sofa for two in the Rolls-Royce Vision Next 100.

Passenger entry and egress sees roof and coach doors opening. Occupants would stand to step from the vehicle onto a light-projected red carpet effect. Their bespoke luggage would be housed in a compartment between front wheel and side door.

A virtual intelligence capability would control the vehicle, embodied in a digital representation of the Rolls-Royce Spirit of Ecstasy mascot. This would appear on a full-width transparent OLED display. Called Eleanor after the human model that posed for the original mascot, the more time spent with a passenger the more "she" learns of their preferences in terms of favored routes, restaurants etc.

A real mascot of hand-cut lead crystal with interior illumination (yes, really) would adorn the car's traditional Palladian-style radiator grille. Of course, all this must not be taken too literally. But there is some indication of future thinking. And it is good to see technology imbued with a fun factor.

The company states: "The customer's taste will shape exactly how his or her Rolls-Royce will look and how it will be configured." So a production derivative of the Vision100 might itself prove entertaining.

As Adrian van Hooydonk, Head of Group Design at Rolls-Royce's parent company **BMW** sums up the Next 100 concept: "It is an enlightening vision of the fascinating possibilities of Rolls-Royce Motor Cars in the future."

Would Sir Henry now regret his words uttered long ago, or applaud the freedom of design that may be in prospect if Vision becomes reality? Good or ghastly? Only the next 100 years will tell.

Stuart Birch

AUTOMOTIVE INTERIORS

Quest for 'new-car smell' dictates interior materials changes

Benecke-Kaliko's Xpreshn surface material accents a soft-touch feel.

The sensory elements of smell, touch, sound and sight are influencing material innovations for vehicle interiors more than ever.

Chinese buyers abhor certain new-vehicle smells. And with forecasters at **IHS Automotive** projecting annual light-duty passenger vehicle sales in China to reach 29 million by 2020, there are obvious financial motivations for ridding car and truck interiors of the objectionable odors associated with certain widely-used plasticizers and adhesives.

"That odor kind of goes hand-in-hand with VOC (Volatile Organic Compound) requirements—and China to a certain extent is going to lead how VOC limits are set," Rose Ann Ryntz, Ph.D., Vice President of Advanced Development & Material Development at **International Automotive Components** (IAC), said in an interview with *Automotive Engineering* at the 2016 **WardsAuto** Interiors Conference in Detroit.

Although it's unlikely that all OEMs will have the same VOC specification standards, moving to organic chemicals is on the industry's docket, said Ryntz, moderator of a materials innovation panel at the conference.

"We're moving away from VOC-laden PVC slush [programs] at IAC, and we're looking to do more with polymeric plasticizers for slush PVC as well as slush TPE-type [projects]. We're also looking at how the construction of vacuum formed bi-laminates are put together with adhesives, since the adhesives can be a big source of VOC and odor," she said.

This door bolster is made from kenaf, a natural material. Manufacturer IAC uses adhesives to build up the layers before the unit is assembled into a door panel. The company is looking at how the construction of vacuum formed bi-laminates are put together with adhesives since adhesives can be a source of VOC and odor.

3M debuted a new line of low-VOC attachment tapes at the WardsAuto conference. These thin tapes are designed for armrests, center consoles, instrument panels, door bolsters, and other interior applications that require bonding and dimensional stability during lamination.

The recently launched Xpreshn Lux, a low VOC surface material in **Benecke-Kaliko**'s Xpreshn product line, gives a soft-touch sensation to instrument panels, door trims and other cabin locales, according to Dominik Beckman, the company's Global Director of Marketing and Innovation Management. Benecke-Kaliko is part of the **ContiTech** group.

"It has an ultra-soft lacquer coating, and the formulation is ultra-soft as is the foam layer. The whole construction is ultra-soft. It's more than just a soft foam, Beckman said about Xpreshn Lux.

Company officials claim that Xpreshn Lux, making its global debut in the Cadillac XTS sold in China, is up to 500% softer than Tepeo, Benecke-Kaliko's low-density polyolefin foil used in surface materials.

Xpreshn Lux is thermoformed and an up-level Xpreshn version is in the final stages of development.

The new version "will be cut-and-sew for a TPO-type of material, so that's definitely different than the traditional processing method of vacuum-forming," Beckman said.

Kami Buchholz

TRUCK ENERGY | INTERIORS

NREL cost-effectively eliminates diesel idling to condition Class 8 sleeper cabs

You see them at the side of roads, in parking lots and pull-off areas of highways—Class 8 over-the-road trucks with their diesel engines idling through the night to run the heating or air conditioning that assure comfort in the resting drivers' sleeper compartments. A lot of fuel might be saved—and CO_2 emissions reduced—with energy-efficient alternatives to extended idling.

The **National Renewable Energy Laboratory**, a federal facility based in Golden, CO, took on the challenge. The idle fuel-usage studies it found were from 2005; the outdated figures estimated idling is 7% of total diesel fuel consumption, so NREL focused on individual Class 8 trucks, proposing a package of technologies that can annually save 774 gallons on A/C cooling load alone compared with an idling truck; at $3 per gallon for diesel fuel, full payback of an investment in sleeper cabin climate-control equipment would come in about three years.

Only about half the states in the U.S. currently restrict idling for over-the-road trucks and laws often are observed in the breach, as some answers raise cost and reliability issues.

Technologies evaluated in the NREL climate-controlled sleeper program. Advanced glazings were used for reference only.

Driver comfort important

The trucking industry and regulators know there's a clear opportunity to save fuel and improve air quality. But resting drivers can't be confined to cocoon-like compartments with an occasional wisp of cool air in summer and/or wrapped in heavy blankets in winter.

Today's sleeper compartments make driver comfort and convenience high priorities. **Volvo** VNL Class 8 series single-bed units are 118 ft^3/3.34 m^3 with a flat roof, and two-driver models with high roofs (77 in/1955 mm) have bunk beds in a 371 ft^3/10.5 m^3 living space—considerable area to be climate-controlled.

NREL's name points to its research in such areas as photovoltaics, wind and biosciences, but much of its work

Test bucks and sleeper cabs were evaluated at NREL's Golden, CO facility. Electrical use was monitored from a 120-V AC source for testing convenience.

Walls of the sleepers were fitted with various packages of upgraded insulation.

Reflective "Thinsulate" was added as part of "plus" insulation package.

is on cost-effective solutions to real-world "lower-tech" problems. It has provided considerable study on climate-control related electric-vehicle range issues and at the 2016 **SAE** World Congress explained its extensive research into reducing Class 8 truck idling fuel consumption.

There are alternative approaches for climate control in sleeper cabs to avoid extensive idling, including battery-powered auxiliary A/C, fuel-fired or electric heaters and small diesel engines that serve as auxiliary power units (APUs). The popularity of diesel APUs peaked some eight years ago and the adoption rate today represents just 9%, explained Jason Lustbader, NREL senior research engineer.

NREL looked at many aspects of what it proposes as "complete cab solutions," with emphasis on low-cost additions or substitutions. "The project goal was to reduce cab thermal loads to enable smaller, lighter and more cost-effective idle-off climate-control equipment," explained Lustbader. The goal: a 30% reduction in big-rig sleeper climate-control loads with no-idle solutions that pay back within three years or less.

The NREL project evaluated four aspects in an integrated strategy: the solar envelope (as overall A/C energy use is in the equation), heat and cold conductive pathways into the sleeper, efficient equipment and the volume of the sleeper. In this effort, NREL works with industry partners, particularly **Volvo Group NA**, **PPG** and **Aearo Technologies**, which makes energy/sound absorbing materials.

35.7% reduction in A/C load

NREL testing showed its complete cab solution exceeded the goal, with its most advanced approach producing a 35.7% reduction in A/C load and 43% decline in heating load, with an even greater reduction of 53% with a more advanced approach to insulation. Translating those savings into dollars, NREL found that with the complete cab solution to reduce loads and adding a battery-powered A/C system for the sleeper, 774 gallons of fuel per year could be saved. Savings and cost analysis for heating the cabin is still underway, although some preliminary data was announced.

Prior testing by NREL indicated the best bang for the buck was in specific insulation, interior curtains, window shades and paints. Although all the actual testing was done at NREL headquarters, the data was plugged into NREL's own load estimating software, CoolCalc, to give the results a nationwide scope. The process provides fuel-use estimation by combining thermal loads with an A/C performance model to calculate an electrical demand. The load was combined with modeling to be able to determine fuel use from recharging the battery pack. Because long-haul trucks operate across the country, the model used the 200 most representative weather stations nationwide to calculate total fuel saved.

Details that led to NREL's quantified results:

Thinsulate in "plus" package

Baseline insulation consists of foam attached to the door and body trim panels of the sleeper. The advanced package instead uses one- and two-inch insulation blankets with a thermal conductivity rating of 0.03-0.05 W/m-K. In addition to that advanced package is a "plus" addition of 0.25-in (6.35-mm) layer of **3M**'s Thinsulate, a synthetic fiber thermal insulation material which has a reflective radiant barrier. It is installed between the interior trim and the structure of the sleeper.

The three levels of insulation for the

Electric forced-air heater was used to measure UA (heating load).

sleeper were combined with three different packages of privacy shades for the cab glass and sleeper curtains between the cab and sleeper: standard insulation with advanced shades and curtains, advanced insulation with standard shades and curtains and a package of fully advanced insulation, shades and curtains. The first two packages produced almost the same reduction in UA (heating load): 20.6% and 20.7%. The fully advanced setup resulted in a 43% reduction.

"Advanced plus" insulation also was evaluated against standard shades and curtains, advanced shades and open curtains and advanced shades and curtains. This "Complete Cab Plus" configuration yielded the greatest reduction in UA at 53%.

However, even with Plus insulation and advanced shades, leaving the sleeper curtains open to avoid a claustrophobic-feeling sleeper caused the heating load reduction to drop markedly to just 21.6%.

No-idle equipment

A **Dometic** no-idle 7000-BTU A/C system was installed. This truck sleeper system is battery-operated, has a three-speed blower and will run for more than 11 hours, the company claims. The system was powered by the laboratory's 120-V A/C for testing to obtain the most accurate data. However, the analysis assumed the use of 104 A-h AGM (absorbent glass mat) batteries that would recharge while the truck is in operation.

For heating, NREL chose a forced-air heater with the diffuser oriented to avoid air stratification. The heater was operated at 90°F (32°C) to provide a sufficient gap compared with ambient temperate for accurate measurement of the heat transfer coefficient (clearly much higher than would be used solely for sleeper comfort). A fuel-fired heater will be evaluated in future testing and it is expected to enhance the overall results.

Paint-color effect

Exterior paint color affects sleeper thermal loads only when the sun is out for a long time and intensity is high, typically in summer. However, because it does affect the total vehicle A/C load, the chosen white color was found to deliver a 20.8% load reduction compared with black. As an alternative, solar-reflective blue was compared with conventional blue and showed a 7.3% saving.

The white color combined with the NREL Complete Cab Plus package to deliver the lab's 35.7% cut in overall A/C energy consumption.

NREL's complete solution delivered results that equate to operating the trucks in year-round moderate temperatures. Modeling with CoolCalc showed major reductions in the number of both heating and cooling days in all parts of the country. This seems to provide an opportunity to save by downsizing the battery pack and other components in a fully optimized Class 8 climate-control system.

Paul Weissler

AUTOMOTIVE MATERIALS

Honda's new e-motor magnet aims to mitigate China rare-earth monopoly

Honda Motor Co. and **Daido Steel Ltd.** recently scored a strategic win when they announced the first production application of a new magnet material for electrified vehicle motors.

The material—hot deformed neodymium—is being used first in a new permanent-magnet traction motor powering Honda's 2017 Freed Sport Hybrid compact minivan. Significantly, the material is not a "heavy" rare-earth metal, one that requires "doping" with dysprosium or terium rare earths to achieve high heat-resistance characteristics. Yet it has the high magnetic and thermal performance necessary for use in EV and hybrid vehicle e-motors, according to the companies.

The new magnet material co-developed with Daido Steel brings Honda one step closer to effectively reducing content of "heavy" rare earths in its e-motors going forward. Cost and reliable supply are the reason: Chinese mines currently supply more than 93% of the world's rare earth elements including neodymium and dysprosium that are essential to scores of magnetic products (though 65% of the world's reserves lie elsewhere).

In 2010, China briefly embargoed

A rotor used in Honda's new e-motor for the 2017 Freed hybrid containing the new magnet material co-developed with Daido Steel.

exports of rare earths to Japan after a maritime incident involving one of its fishing boats allegedly operating in Japanese waters. Increased tensions with China over disputed oceanic boundaries, the metals embargo and opportunity to reduce material cost likely prompted Honda powertrain planners to develop less risky alternatives to replace the heavy rare-earths, according to experts.

The **U.S. Dept. of Energy**'s REACT (Rare Earth Alternatives in Critical Technologies) program also aims to find low-cost and reliable alternatives for rare earths.

Although classified as a rare earth, neodymium (Nd) is a fairly common element, no rarer than cobalt, copper and nickel. When compounded with iron and boron (Nd2Fe14B), it inherently offers much greater magnetic strength than other permanent magnets, allowing use of smaller, lighter magnets in a wide range of commercial applications.

Daido Electronics, a subsidiary of Daido Steel, has been mass-producing neodymium magnets using hot deformation. The process differs from sintering which is typically used in magnet production. Hot deformation enables nanometer-scale crystal grains to be precisely aligned. The resulting crystal grain structure is approximately 10 times finer than that of a sintered magnet.

This makes it possible to produce magnets with greater heat resistance properties without the need for doping with the expensive "heavy" rare earths. To accommodate the new magnet Honda designed a new traction motor with a revised rotor shape designed to optimize the flow of the magnetic flux.

A market for the newly-developed hot deformed neodymium magnet opens the door for Daido Steel into the global electrified vehicle supply chain, which for traction-motor magnets has been dominated by sintered Nd magnets. Daido Electronics built a new production line at its Nakatsugawa City plant, and sources its magnetic powder from **Magnequench International** in Toronto, Canada.

Coincidentally, the Nd2Fe14B magnet alloy was developed in 1982 by *and **Sumitomo Specialty Metals** in response to the high cost of samarium-cobalt (SmCo) magnets.

Lindsay Brooke

OFF-HIGHWAY CHASSIS

Corrosion-resistant bearings extend equipment lifetimes in severe environments

High nitrogen corrosion resistant bearings can reduce failures in harsh environments like military landing craft.

In harsh environments, relatively small problems like corrosion in a bearing can stop multi-million dollar vehicles where they stand. **SKF** and **Textron** are betting that bearings made with high nitrogen corrosion resistant (HNCR) stainless steel technology can reduce downtime on a military landing craft.

Stainless steel bearings common in equipment made for harsh environments have long been regularly replaced to avoid seizing and freeze up. It's typically costly to replace bearings buried deep inside equipment, so a team within SKF's aerospace group that focuses on blank sheet engineering and cutting edge technology has used the material in a line dubbed MRC.

"This is one of the largest advances in bearings in a while," said Laurie Olson, Specialty Marketing Manager at SKF USA Inc. "This is the first completely non-corrosive stainless steel used in a bearing."

Textron is using the MRC line in a Ship-to-Shore Connector used by the **U.S. Navy** to move personnel and equipment. Textron received a $213 million detail design and construction contract in July 2012 to build a test and trial craft.

That contract has since been expanded to nine vehicles that use Textron's Landing Craft Air Cushion technology to hover above the water and move onto shore. They will employ a fair number of SKF's bearings.

"We're providing 13 sets of bearings for the new model, which has been in testing for two years," Olson said. "This meets all the load requirements and reduces corrosion so our bearings can meet the U.S. military's 25-year lifetime requirement."

SKF has made HNCR in very limited production for a few years, employing HNCR bearings in applications as diverse as cranes and ice cream production equipment. That's now changing as SKF's manufacturing teams improved production techniques and test results showed good results.

"This is now ready for prototypes and small lots; it's something we haven't been able to provide before," Olson said. "This will not become a commodity item; you're not going to open our catalog and see HNCR bearings."

The material has been used in a crane used to move materials from ship to shore for over five years, much akin to the Navy application. In an ice cream hardening tunnel, bearing lifetime went from around a year to more than five years, according to SKF.

Terry Costlow

AUTOMOTIVE MATERIALS

NanoSteel confident its new AHSS is ready for volume production

Steel-technology development specialist **NanoSteel** is expanding its customer base for the new advanced high-strength alloys currently undergoing testing by OEMs and Tier 1s, as global automotive demand for stronger, lighter vehicle structures increases.

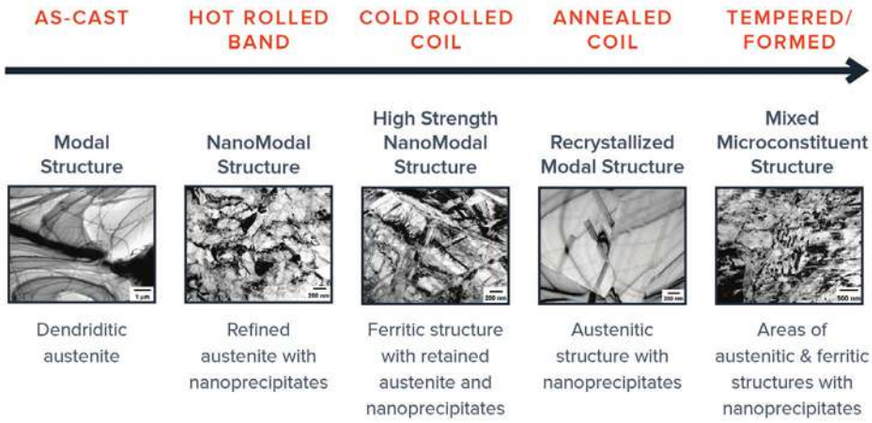
The Rhode Island-based company, which emerged on the auto-steel scene 12 years ago, also is working with additional steel mills to produce the AHSS sheet, according to David Paratore, CEO and President.

Last spring, **NanoSteel** delivered its first production-scale AHSS to **GM** and other OEMs for initial evaluations. (**GM Ventures**, the automaker's venture-capital arm, is a lead shareholder.) Joint development partner **AK Steel** was the first steel producer to manufacture this AHSS using traditional slab casting.

NanoSteel metallurgists delivered the breakthroughs necessary to enable the slab casting process in early 2014. The technique typically uses 8- to 10-in (203- to 254-mm) thick steel slabs to produce automotive sheet, Paratore explained to *Automotive Engineering*.

Since then, the two companies have been overcoming hurdles to commercialize the product. In Paratore's words, NanoSteel is now focused on execution, not technology.

"We needed to pay our dues, so to speak," he said. "We went through all the ups and downs that come with taking a new material from the lab to commercial scale, but we're over those hurdles now. And we're pretty confident we could produce the material on a regular basis."



Over the past two years, NanoSteel and AK Steel have focused on the producibility of its AHSS. This image details the structural changes in NanoSteel's steel at different stages of the production process.

One of those hurdles was designing an alloy that could create the desired microstructures at much slower cooling rates. "Originally, our materials needed to rapidly solidify," Paratore noted. "One of the major breakthroughs that we needed was to make our materials resilient to cooling rate. Now we can withstand the cooling rate that is natural in a 10-in-thick piece of steel."

Another challenge was narrowing the initial liquid-to-solid temperature gap. "Our alloys typically had a very large gap between the two, around 150 to 170°C," he said. "That much energy had to be pulled out during the solidification during the casting process, which was too much. So we had to design an alloy that also shrunk that gap to a reasonable number for steel mills' equipment."

The material that NanoSteel supplied to GM is about 1200 MPa and 50% elongation. The company's next product will most likely be higher strength but sacrifice some elongation—for example, in the range of 1500 MPa and 30% elongation, said CEO David Paratore.

NanoSteel now affectionately refers to its materials as LGs, for "low gaps." Refinements have also resulted in "substantially" improved properties and enhanced lightweighting capability, said Paratore.

Tensile strength of the material supplied to GM is approximately 1200 MPa and ductility is measured as 50% elongation. The company has "quite a few [other] alloys already designed and 'sitting on the shelf,'" Paratore revealed. He said the next product will most likely be higher strength but sacrifice some ductility—for example, in the range of 1500 MPa and 30% elongation.

NanoSteel is marketing its AHSS as being both easy to produce and to work. Production involves conventional alloying elements with standard slab casting equipment. Stamping and forming of parts is done at room temperature without additional manufacturing infrastructure or investment, such as that required for 'hot' stamped parts, he claimed.

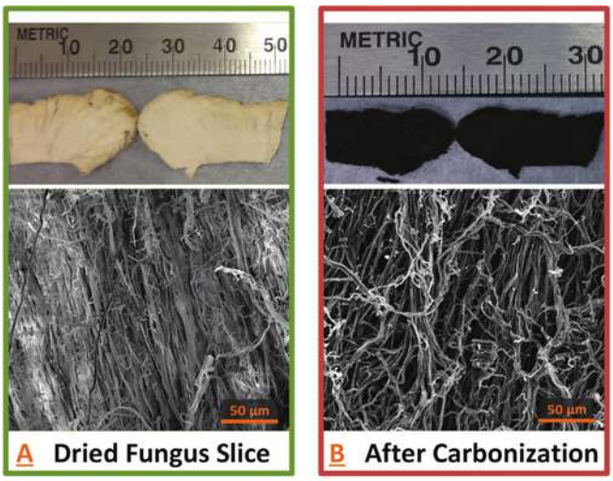
"Our intent is to be able to produce our steels in all the major processes for automotive—electric arc furnace (EAF) and blast furnace in the creation of the actual melt," Paratore said. Thin slabs—less than 5 in (127 mm) thick—is another goal.

"Those are the other pieces of this puzzle that we want to move along simultaneously," he asserted, "because one of the fundamentals to NanoSteel's business model is global availability."

Ryan Gehm

AEROSPACE | AUTOMOTIVE MATERIALS

Fungus-inspired improvements in battery performance



Microscope images of a type of wild fungus shows that it contains an interconnected network of fibers ideal for battery anodes. (Purdue University/ Jialiang Tang)

Carbon fibers derived from a sustainable source, a type of wild mushroom, and modified with nanoparticles have been shown to outperform conventional graphite electrodes for lithium-ion batteries.

Researchers at **Purdue University** have created electrodes from a species of wild fungus called Tyromyces fissilis.

"Current state-of-the-art lithium-ion batteries must be improved in both energy density and power output to meet the future energy storage demand in electric vehicles and grid energy-storage technologies," said Vilas Pol, an Associate Professor in the School of Chemical Engineering and the School of Materials Engineering. "So there is a dire need to develop new anode materials with superior performance."

The anodes in most of today's lithium-ion batteries are made of graphite. Lithium ions are contained in an electrolyte, and those ions are stored in the anode during recharging.

Pol and doctoral student Jialiang Tang have found that carbon fibers derived from Tyromyces fissilis and modified by attaching cobalt oxide nanoparticles outperform conventional graphite in the anodes. The hybrid design has a synergistic result, Pol said.

"Both the carbon fibers and cobalt oxide particles are electrochemically active, so your capacity number goes higher because they both participate," he said.

The hybrid anodes have a stable capacity of 530 mAh/g, which is one and a half times greater than graphite's capacity.

One approach for improving battery performance is to modify carbon fibers by attaching certain metals, alloys or metal oxides that allow for increased storage of lithium during recharging. Tang got the idea of tapping fungi for raw materials while researching alternative sources for carbon fibers.

"The methods now used to produce carbon fibers for batteries are often chemical heavy and expensive," Tang said.

He noticed a mushroom growing on a rotting wood stump in his backyard and decided to study its potential as a source for carbon fibers.

"I was curious about the structure so I cut it open and found that it has very interesting properties," he said. "It's very rubbery and yet very tough at the same time. Most interestingly, when I cut it open it has a very fibrous network structure."

Comparisons with other fungi showed the Tyromyces fissilis was especially abundant in fibers. The fibers are processed under high temperatures in a chamber containing argon gas using a procedure called pyrolysis, yielding pure carbon in the original shape of the fungus fibers.

The fibers have a disordered arrangement and intertwine like spaghetti noodles.

"They form a conductive interconnected network," Pol said.

The interconnected network brings faster electron transport, which could result in faster battery charging.

Jean L. Broge

AUTOMOTIVE SIMULATION

Jaguar, Exa say simulation to eliminate prototypes by 2020

Finding the right ratio of "emphasis" (aka "compromise") between design and engineering priorities has long been part of the enduring magic behind the conception and creation of vehicles.

Today's increasingly advanced CAD and CAE software solutions have arguably eased this tension and reduced the longstanding conflict to more of a mere tussle, but now it's going a step further: **Jaguar Land Rover** (JLR) and its close partner, simulation-software expert **Exa Corp.**, say design software has become so sophisticated that by 2020 they can eliminate the need to build physical prototypes of a new vehicle under development.

At later stages of development, there always will be the need for driveable prototypes, of course. But the two companies said Exa's integrated visualization tools—and Jaguar's decade-plus of focused experience in applying them—create a technology platform for state-of-the-art, simulation-driven development that they project can eventually eradicate prototypes.

Jean-Paul Roux, Paris-based President of European Operations for Exa, explains: "Carmakers that utilize visualization modules integrated within CAE software, such as Exa PowerFLOW, are beginning to reap the benefits of immersive, photorealistic rendered representations of every stage of the design process."

Long gone are the days of "stock" presentation software for communicating intricate and continually changing design phases as carmakers "step into the future," he asserted.

He emphasized, for example, that gaining a clearer understanding of which design feature impacts which area of aerodynamic performance on a vehicle plays an integral part in creating a more open discourse between the design studio and engineers: "This allows both parties to undertake the creative process with one another's priorities and objectives in mind, actually resulting in bolder and more expressive

Exa aerodynamic simulation applied to the Jaguar XE.

design concepts with greater aerodynamic capabilities."

Roux added that large-scale, latent- or minute-flow dynamics now can be detected to what he terms "the utmost degree of accuracy" with these sophisticated visualization tools—and such intricate views are not available in the wind tunnel: "This provides design and engineering teams with a level of insight into their conceptual alterations, in real-time, which revolutionizes what components look like and how they are created."

Jean-Paul Roux, President of Exa's European Operations.

JLR used Exa's system for the XE, which particularly helped to achieve excellent aerodynamics (a best Cd figure of 0.26) without requiring excessive styling compromises. In what may amaze many rivals, JLR did not use a single physical aerodynamic prototype during development of the XE — all aerodynamic optimization was done exclusively through Exa PowerFLOW simulation, Ales Alajbegovic, Exa's Vice President of Ground Transportation Applications, told *Automotive Engineering*.

Mark Stanton, JLR's Director of Special Vehicle Operations (SVO) and formerly its Director of Vehicle Engineering, said, "We use Exa for all of our current-production vehicles to work on development of the aerodynamic properties of those vehicles. Another example is the F-Pace (crossover). Here we use Exa to achieve perfect lift balance—you have seventy 'counts' of lift on the front and rear, which really contributes to the sporty driving experience of the vehicle.

"We've also used it [Exa simulation software] to help improve the aerodynamic drag," Stanton continued. "We have apertures in the front bumper which we use to turn the airflow around the front corner to really improve the aerodynamic efficiency of the vehicle.

"All of this," he said, "was done in the virtual world before we ever had any physical properties. We really only validated with a physical (prototype) right at the end of the process, as we have all of the confidence in these virtual tools."

Aligning design with engineering

Paul Stewart, Exa's Design and Visualization Director at the company's Burlington, Massachusetts, headquarters, added that when working on different timescales—perhaps with conflicting objectives—it had not been uncommon for designers and engineers to find themselves out of sync when working on the same project, particularly when day-to-day contact may be limited.

No actual road-burning here, but a simulated version of Jaguar's XE sedan with Exa's visualization software at work.

"What some carmakers have now discovered, however, is that simulation-driven design can help repair this disconnect thanks to integrated visualization tools provided in CAE software such as Exa PowerFLOW."

Stewart said that for both designers and engineers, simulation software provides an "intricate" real-time understanding of design alterations: "This doesn't mean that designers are now having to concede ground on more daring projects—quite the opposite, as this holistic approach to design encourages multidisciplinary collaboration right from the start of the development process, resulting in expressive yet feasible designs."

Mark Stanton, Jaguar Land Rover Director of Special Vehicle Operations (SVO).

Beyond aerodynamics to full-vehicle validation

Jaguar is confident about its 2020 timeframe for eliminating prototype builds largely because its decade of collaboration with Exa has generated an "evolution" of prototype reduction, starting with the elimination of earliest prototype phases, said the Exa spokesperson.

Stanton confirmed the company is aiming to achieve full-vehicle verification exclusively through digital simulation by 2020, going straight from virtual into the final physical production vehicle: "The use of Exa software now is really key in what we do at Jaguar Land Rover. We used over 36 million hours of CPU time in 2014 on Exa and that's the equivalent of about 7000 physical wind tunnel tests, so that's pretty immense!"

He added: "We are trying to 'left shift' (from physical) our engineering, and virtual engineering is absolutely a key part of that shift. It enables us, far earlier, to validate that we have met all requirements for the program and ensure that we have the quality baked in right up front."

Meanwhile, Exa's Alajbegovic asserted that full-vehicle verification by simulation likely will generate immense cost and time reductions in the product-development process.

"The most significant cost savings when an automaker commits to virtual design comes from avoiding late changes and fixes," he said. "Late-discovery and fixes that prompt a one- or two-month delay of the market launch can cost an automaker hundreds of millions of dollars. Problems requiring tooling changes also cost several million dollars. (Improved) ability to design vehicles on cost and time will be enabled using virtual design."

Apart from process savings, reducing or eliminating prototypes also will have a significant bottom-line impact, Alajbegovic added. "Considering just the prototype vehicle costs (not including testing costs), static clay models may cost between $500,000 to $1 million per unit and traditional automakers may build two or three models for early testing," he said. "Drivable prototypes may cost between $500,000 - $1 million per unit (depending on the carryover versus prototype-parts content), with automakers building between 100-200 driving prototypes for physical tests."

Roux opened the company's Paris office in 2002, further expanding the company's client list. Together with JLR, that lineup now includes **BMW**, **Delphi**, **Denso**, **Fiat Chrysler**, **Ford**, **Honda**, **Hyundai**, **Nissan**, **Peugeot**, **Renault**, **Toyota**, **VW** and major commercial vehicle and off-highway companies.

Stuart Birch and Bill Visnic

AEROSPACE TESTING | DESIGN

The future of better drones is for the birds

David Lentink, an Assistant Professor of mechanical engineering at **Stanford**, has been studying birds in flight with an eye toward applying the tricks birds use to navigate changing conditions in the real world to design better drones. Most of the insights he and his colleagues have gained so far have resulted from painstaking study, involving calculations of wing force dynamics inspired by footage captured in the wild.

Now, with the construction of "one of the most advanced bird wind tunnels in the world," Lentink hopes to reveal even more of the magic of bird flight.

Drones have historically failed to maintain control, and thus the mission, when attempting to do so under windy conditions. Pigeons, not so much. "You look up, and you'll see a pigeon swoop by casually. It has no problem stabilizing itself, flying around corners, dodging cables, and landing on a perch," Lentink said. "We need to study birds up close so we can figure out what their secret is to flying so stably under such difficult conditions, and apply that to aerial robotic design."

The new wind tunnel is described as working "like a super tricked-out treadmill for birds." The windflow, generated by a fan roughly the size of a compact car, is super smooth: Turbulence checks in around 0.015%, less than half of any other bird wind tunnel in the world. This allows the researchers to study how birds fly in smooth-flowing air such as that found at higher altitudes.

Such conditions aren't typical closer to the ground, particularly around trees and buildings, though, so the tunnel is fitted with a "turbulence generating system," a series of computer-controlled wind vanes that can precisely simulate different turbulence patterns, creating up to 50% turbulence. In this state, the flow moves almost equally randomly in all directions, making it very unpredictable for the bird.

Wind speed is highly tunable. The lovebirds, parrotlets, and hummingbirds that Lentink's lab studies typically cruise around 7 m/s, which the engineers can match perfectly to study sustained flight. They will occasionally crank the flow up to 15 m/s, which simulates a strong wind, maxing out at 20 m/s for large birds. The tunnel can blow much faster, however, with speeds up to 50 m/s for the prototype drones he plans to test in the tunnel.

A lovebird flies near Stanford mechanical engineering Assistant Professor David Lentink, who is using a wind tunnel to probe the mysteries of birds in flight. (L.A. Cicero)

Nearly 2 m long, the six-sided windowed observation section of the tunnel provides a variety of ways to study bird flight. Lentink's team can currently zero in on specific aspects of birds' wing beats, using high-speed cameras as well as motion capture techniques, recording wing motion millisecond by millisecond. They then translate these measurements to precise calculations of the force dynamics experienced along the birds' wings and in the surrounding air. Later this summer, Lentink expects to introduce two fluoroscopes to the mix, which will allow researchers to "see inside" the bird and visualize the exact muscular-skeletal movements it makes in different flight maneuvers.

Once his team has trained enough birds, Lentink plans to fly entire flocks in the tunnel to determine how turbulence created by one bird's wing beats affects a nearby bird, and how they maneuver for position.

Using the information gleaned from bird flights, Lentink envisions using the tunnel as a test-bed for new drone designs. In addition to establishing better maneuverability controls for common quadcopter designs, he's particularly interested in building bird-like, winged drones that quickly morph their wing shape to maintain stability in turbulent air flows.

"Ever since Otto Lilienthal and the Wright Brothers studied birds to invent their airplanes, engineers have relied on talking with biologists to learn the tricks birds us," said Lentink, who is a member of Stanford Bio-X. Although the wind tunnel will enable engineers to develop safer and more reliable drones that fly in urban environments as well as birds do, Lentink stressed that it is not only an engineering facility, but also a biology lab.

Lentink, who is both a biologist and an engineer, teaches engineering students and biology postdocs how to collaborate. "I'm really excited about the opportunity to study bird flight up close with engineering students who bring different interests ranging from biomechanics to fluid mechanics to aeronautics in our team of engineers and biologists."

The wind tunnel was paid for by Stanford. The various measurement systems were acquired with support from the Air Force, Navy, Army, Human Frontiers Science Program, and Stanford Bio-X program.

Jean Broge

Types of aircraft passenger-escape systems

An overview of existing and potential new methods for assuring aircraft occupant safety

Evacuation slide (image courtesy UTC Aerospace Systems)

Background

The safety of the passengers and crew is of utmost importance in aviation, irrespective of aircraft size or civil or military sector. Designers take all precautions while designing the aircraft to enhance the reliability of various systems to address potential component or system failures. They add extra engines, redundant hydraulics, flight controls and electrical and navigation systems.

Redundant components add extra cost and weight to the aircraft but the safety of passengers and crew outweighs these disadvantages. A comparison of accidental deaths in India in 2014 shows the number of casualties was maximum in motor-vehicle accidents (169,107 or 53.4%) and minimum in air crashes (15, or .005% of the total).

Today, air travel is considered the safest mode of transport and has survived because the safety of passengers always remained the most important aspect of the aircraft industry. But despite designed-in backup measures, sometimes aircraft mishaps are unavoidable—and occupants' lives could be in danger. To address this inevitability, the aircraft industry has evolved many solutions. In these unfortunate situations, pilots have to make the emergency landing on ground or water or sometimes they must abandon the craft in the air to save themselves and other occupants.

In this paper, we present an overview of the different types of aircraft passenger-escape systems.

Types of escape systems

In the event of aircraft landing unexpectedly on water or ground, emergency evacuation is to be carried out at a fast pace. Immediate and urgent movement of passengers away from the aircraft is necessary, as after an emergency landing, proximity to the aircraft is inherently unsafe and little time is available for the passengers to escape in these critical situations.

Over a period of time, many technologies have found a role for handling emergency situations in various types of aircraft. The following discussion speaks to current and future technologies intended to make air travel safer.

Emergency exits

Regulatory authorities have ruled that all passengers must be evacuated within 90 seconds. The time necessary for evacuation is influenced by many factors concerning the airframe (the usable number of exits, position, size and number of seats and aisle arrangements), the passengers (age, health, gender, passenger interrelationships and level of panic) and flight crew (skill, assertiveness and training level). The maximum number of passenger seats permitted depends on the type (size) of fuselage and the number of exits installed on each side.

Life jackets

Life jackets help passengers to stay afloat for an extended period after emergency ditching in water and are mandatory for aircraft flying over ocean. They generally consist of two cells or bladders that can be inflated by breathing into inflation tubes or by triggering the release of carbon dioxide from a bottle. Life jackets must be stowed in a place where they are easily accessible to the passengers in emergencies.

Evacuation slide/life raft (image courtesy UTC Aerospace Systems).

Helicopter flotation gear (image courtesy GKN).

Evacuation slides

An emergency at takeoff or landing always necessitates quick evacuation because of the risk of injuries due to fire, explosion or sinking in water. A common method for fast evacuation of passengers and crew from an aircraft is to provide multiple emergency exits equipped with inflatable evacuation slides. Using slides, passengers can quickly and safely slide to the ground from the raised height of the aircraft door.

An escape slide is required on all passenger aircraft where the door sill height is such that, in the event of an evacuation, passengers might not step down from the door unhurt. It therefore is necessary that all modern aircraft are equipped with emergency slides to enable quick and safe evacuation of occupants.

Life Raft

If the aircraft makes an emergency landing on the water, passengers need to be evacuated and immediately boarded in life rafts before the aircraft sinks. Life Rafts are emergency flotation devices inflated by gas into rafts to support and sustain the occupants.

Special slide rafts can first be used as emergency slides then can be converted to a raft following evacuation. Slide/rafts usually feature an erectable canopy, outer compartments to hold passengers and survival packs containing items such as food, medicines and first aid, signal devices, sea dye markers and other vital equipment.

Flotation gear

Flotation gear enables a helicopter to alight on water and remain afloat during passenger evacuation. This equipment is attached to the helicopter's landing gear. Upon contact with water, the floatation gear is inflated with gas and can keep the helicopter afloat for a certain time. While the helicopter is afloat, passengers can be safely evacuated using life rafts before the helicopter sinks.

Ejection seat

In fighter aircraft, an ejection seat is a system meant to rescue the flight-crew members in an emergency. Generally, the seat is propelled out of the aircraft by an explosive charge or rocket motor, carrying the pilot with it. When the pilot is clear of the aircraft, the ejection seat deploys a parachute and the pilot lands safely. Ejection seats have saved the lives of many military aircraft pilots.

Parachute

For crew members other than those in the cockpit of a military aircraft, a parachute provides the option to jump from the aircraft in case of emergency. A parachute slows descent by creating drag and typically is constructed of light, strong cloth such as silk or nylon.

Escape capsule

An escape crew capsule allows a pilot (or astronaut) to escape from the craft while it is subjected to extreme conditions such as high speed or altitude. The crewman remains encapsulated and protected until such time as the external environment is suitable for direct exposure or the capsule reaches the ground.

Types of aircraft passenger-escape systems

Ejection seat (image courtesy *Aviation News*).

Detachable cabin (Image courtesy *Daily Mail*)

Detachable Cabin

Recent reports indicated a Ukrainian engineer had proposed a radical concept of a "detachable cabin" to save airline passengers in the event of an emergency. During take-off, landing or flight, the specially designed cabin can detach from the plane and safely land on the water or ground—saving all the passengers seated in the cabin.

A similar concept was used in the 1960s and 1970s for the F-111 and B-1A military aircraft; designers introduced a method of jettisoning the entire front fuselage as a means of escape for the entire flight crew. The crew remains strapped in the cabin, unencumbered by a parachute harness, while thrust from rockets pushes the module away from the main fuselage. A single, large parachute then brings the capsule down. On landing, an airbag system cushions the landing. In the event of a water landing, the airbag acts as a flotation device.

Conclusion

These aircraft escape systems are designed to ensure that passengers will be able to escape safely in any emergency situation. In addition, statistics show that travel by air is the safest of all modes of transport. Among the variety of aircraft escape systems used or being considered, some concepts have been successfully in service for many years and some are still in design phases. Noting current trends in technology advancement, it seems certain that in the future there will be still fewer casualties connected with air travel. ■

Authors: Sachin Vishnoi, Principal Engineer at UTC Aerospace Systems, Bengaluru, has approximately 20 years of experience in aircraft industry in various organizations such as UTC, NAL, Capgemini, QuEST Global and Mesco Airlines and S.M. Prakash, Technical Lead at UTC Aerospace Systems, Bengaluru, has approximately 10 years of experience that includes positions at UTC and Sonovision-Aetos Technical Services.

SAE SKILL INDIA INITIATIVE: S²I²

A new SAEINDIA collaboration aims to help young engineers acquire "industry-ready" skills

The Indian auto industry is the third-largest in the world and is poised to become first in small vehicles and engines by 2022. In accordance, several initiatives have been undertaken by the government of India and major automotive industries to make the country a leader in the vehicle market.

So there is an increasing need for industry-ready engineers equipped with outstanding skills and equivalent knowledge. Knowledge comes from learning, but "skill" is how we apply the knowledge for a desired outcome. Engineers acquire considerable knowledge through theoryduring their foundational and professional engineering education. But many may not be successful in applying their acquired knowledge to practical work—this demands "skills."

Unfortunately, these skills typically are not taught as part of an academic program and usually are downplayed by both academic institutions and students. The number of engineering colleges in India is expanding at a rapid pace, with 3300-plus colleges as of 2015. From these institutions, more than 1.5 million newly-degreed engineers are graduated annually.

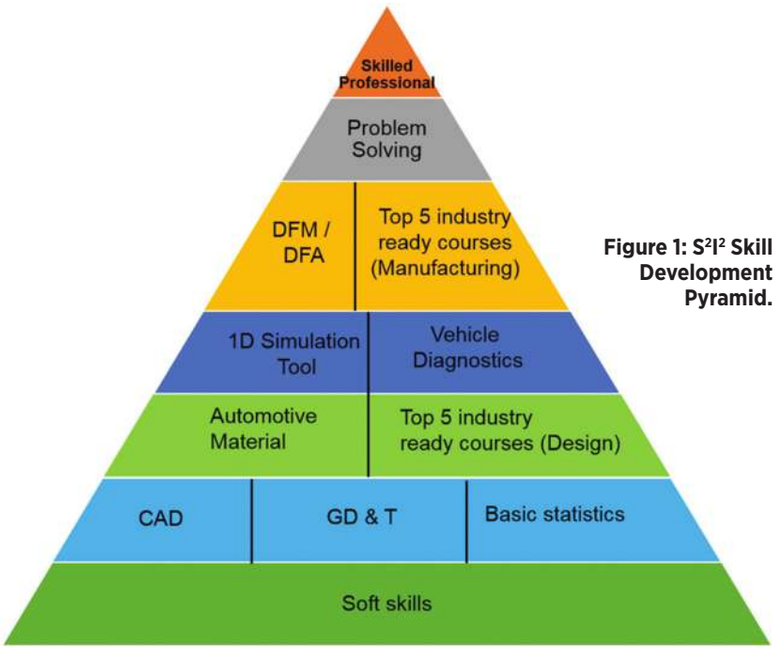


Figure 1: S²I² Skill Development Pyramid.

According to Aspiring Mind's National Employability Report, which is based on a study of more than 150,000 engineering students in 2015 who graduated from more than 650 colleges, 80% are unemployable. The "employability" of engineers in information technology (IT) services—where the only hiring criteria is that the candidate should be trainable in technical and soft skills—is about 17%.

This alarming unemployable rate clearly emphasizes a "skill gap" among India's young engineers.

Understanding the importance of skill development, Prime Minister Shri Narendra Modi recently launched a national skill-development mission. He also has shown his commitment by releasing a national policy establishing a skill-development and entrepreneurship program in partnership with the **Automotive Skill Development Council** (ASDC).

To spearhead the cause and help to develop more industry-ready engineers, Dr. Pawan Kumar Goenka, Executive Director and Group President, **Mahindra & Mahindra**, during a recent meeting with SAEINDIA, asked the organization to assume a larger role in creating global-quality engineers; SAEINDIA and ASDC thus initiated the SAE Skill India Initiative (S²I²)

Course outline	Importance /10	No of Units
CAD	3	2
GD&T	7	2
Automotive Material Selection	5	3
1D Simulation	5	2
Top 5 industry ready courses (Manufacturing)	9	4
Problem Solving	7	3
Basic Statistics	5	2
Top 5 industry ready courses (Design)	9	5
DFM / DFA	5	3
Vehicle Diagnostics	5	2
Soft skills	3	2

Grading	GPA / 10.0 Scale
A	10 – 8.5
B	8.5 – 7
C	7 – 5
D	Reappear

Table 1: S²I² Skill assessment and grading method.

wherein specific domain engineers (mechanical, automotive, manufacturing, production technology, industrial engineering, mining, rubber and plastic technology, mechatronics and metallurgical) will receive skill training based on current and projected industry demands.

Current skill programs in both public and private institutes focus almost exclusively on the "soft" skills required to be successful during campus job interviews. Although ASDC's primary emphasis is on blue-collar jobs with manufacturing and quality aspects, the objective of S²I² is to work closely with engineering colleges and industry to impart technical skills for product development, application engineering and research-and-development engineering jobs in which skill development ultimately leads to competency development—competency being the amalgam of skill, knowledge and ability.

The Objective, Mission and Scope of S²I² are as follows:

Objective

- Make engineers "industry-ready"
- Improve the competency of the engineering graduates to fulfill mobility industry objectives
- Help engineers succeed in their job with high competency and skill

Do's	Don'ts
Project • Think of doing a project of small engineering depth.	• New vehicles, concepts and extreme engineering.
Intercollegiate vehicle design competitions (SUPRA, BAJA, Efficycle) • Try to participate and deeply understand a specific area of your endeavor. • Make your technical area stronger (e.g. crash analysis or bolted-joint design or power steering design)	• Outsource project work
Internships • Undergo internships and acquire hands-on experience with defined objective and scope.	• Seek short-term (days-long) internships for a certificate/with no objective in hand.

Table 2: Do's & Don'ts for skill development.

Mission

- Improve the employability of professionally qualified engineers by imparting them with skills required by the current and future automotive industry.
- Enhance engineering skills to generate advanced and creative solutions that lead to innovation.
- Fuel the growth of "Make in India" and envision an "Innovate and Design in India" global approach.

Scope

- Train engineering graduates from First year to Final year (F2F).
- Focus on chief engineering disciplines—mechanical, automotive, manufacturing, production technology, industrial, mining, rubber and plastic technology, mechatronics and metallurgical.

The skill gap among graduating engineers is the result of mismatch between demand and quality of supply.

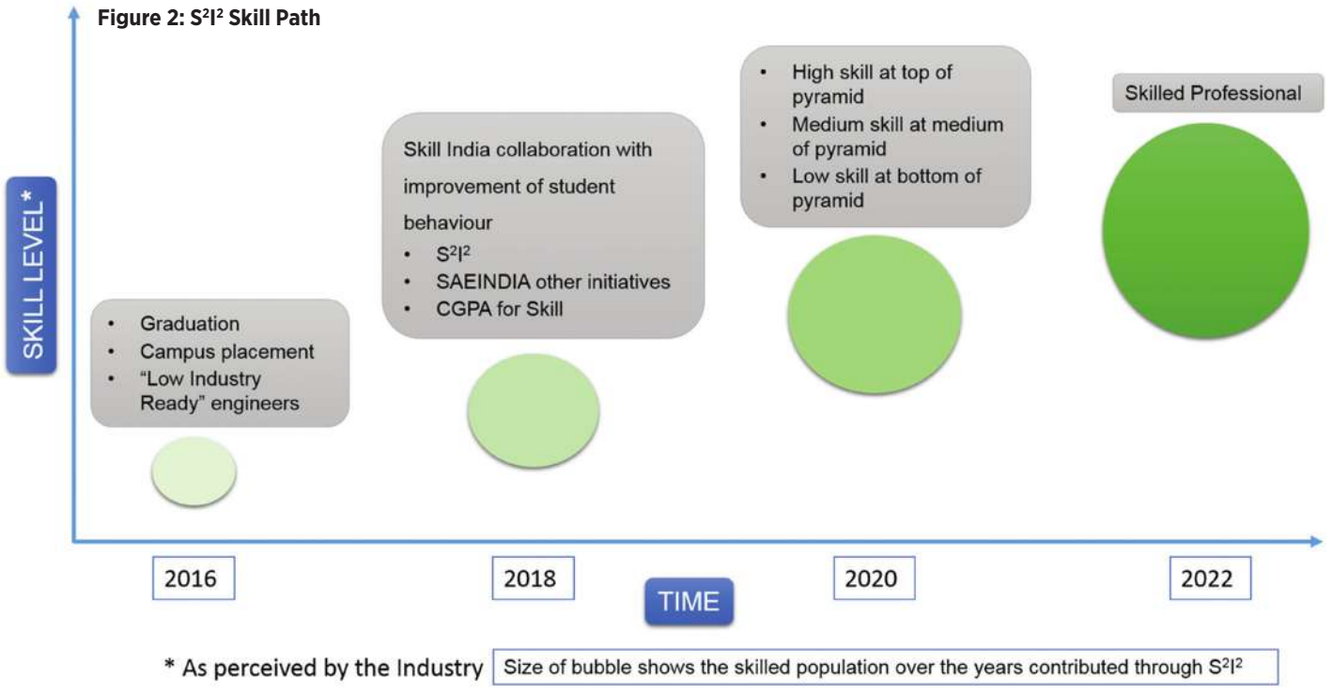
The industry expects engineers to have in-depth knowledge of at least one technical skill area in the automotive domain, including clear understanding of fundamental concepts, unit conversions, engineering drawing, assembly and manufacturing methods. Additionally, hiring companies also expect soft skills such as language proficiency and comprehensive communication and behavioral skills. While most engineering students are on par with the industry expectation regarding soft skills, they fail to meet the requirements for the technical skill set. The amount of skill gap is directly proportional to the choices made by the engineers during their studies.

The S²I² Skill Development Pyramid (SDP) as shown here represents a demand-driven approach. The SDP focuses on imparting key technical skills an engineer must possess before entering into an industry and is devised to progressively achieve the goal of skill acquisition. Rather than focusing on lectures alone, the S²I² SDP emphasizes hands-on-training and also includes the assessment of engineers after each module, which helps students with self-evaluation and certification. Grading is awarded based on their overall performance in different modules (see Table 1).

Summary

S²I² SDP is a novel approach to skill development for engineering students and graduates by adopting a defined skill path. SAEINDIA, a volunteer-driven pioneer organization in the development of engineering education and professional growth, in association with ASDC, will join

Figure 2: S^2I^2 Skill Path



hands with educational institutions and auto-industry experts to support the Prime Minister's "Skill India" Initiative and achieve another milestone.

As stated in the objective, the S^2I^2 SDP imparts skills to the needful engineers in a step-by-step pyramidal approach and makes them "competent" and "industry-ready" through amalgamation of knowledge, skill, and ability. The S^2I^2 SDP model evaluates the performance of the participating students through a well-defined grading method and issues certificates that can be readily recognized and accepted in the industry. The S^2I^2 SDP also has provisions to be dynamic, adapting to changing technology and market needs.

Way forward

1. As a pilot program, SAEINDIA will work closely with educational institutions in Tamil Nadu to identify three colleges to implement the S^2I^2 SDP. During this implementation, Subject Matter Experts (SMEs) and SAEINDIA industry volunteers will define the course content and hands-on-training exercises and train the students to enhance their skill levels in line with similar SAEINDIA programs such as the Automotive Student Orientation Program (aSOP).

2. SAEINDIA will reach out to major automotive companies such as Mahindra, **Ashok Leyland**, **Renault-Nissan**, **Tafe**, **TVS**, **Amalgamations Group**, **Hinduja Tech** and other interested parties to collaborate with them on this pilot program.

3. Future actions include: Certification of specific courses with industry-recognized bodies (weeks 25-30), team development for pilot programs (weeks 30-35), course curriculum circulation and working with pilot institutions (weeks 31 - 36).

4. Meetings between the SAEINDIA Skill Development Group and government bodies such as the **National Skill Development Council** (NSDC) and ASDC to promote and implement the pilot program and generate a roadmap to launch it across India through various sections of SAEINDIA.

5. Implementation and first group of certified-skills professionals (considering engineering students from First year to Final year).

Now comes the appeal to mobility professionals, faculty and students for the successful implementation of the S^2I^2 program. Over a period of time, S^2I^2 and SDP are envisaged to be a part of the college curriculum to enhance harmony in education, skill and competency leading to innovations, socio-economic growth and self-sufficiency.

Our engineering students' ability, interest and knowledge will enable all entities to establish a vibrant industry-institution relationship that develops "industry-ready" engineers—and over time contributes to fundamental research required by the industry to fulfill the "Skill India" objectives. ■

Authors: Dr. Arun Kumar Sampath, GM, Monocoque Platforms, Mahindra & Mahindra, Chennai; Mr. I. Meenakshi Sundaram, Head, Powertrain, Hinduja Tech Limited, Chennai and M. Vimal, Engineer, Powertrain, Hinduja Tech Limited, Chennai.

A TECHNOLOGY-DRIVEN **sustainable-agriculture solution**

A proposed low-cost, GPS-based field-leveling system could improve yields and water-use efficiency in India's rice paddies.

Abstract

Paddy farming in India requires extensive water use. Due to the rapidly declining groundwater and ever-increasing monsoon uncertainty, there is a significant drive on water conservation for paddy farming through sustainable agriculture practices.

The wide depth variability of irrigation water in Indian rice fields, as much as 160 mm, necessitates an extra 100 mm of water in the field to provide complete water coverage. This is primarily due to the inaccurate manual land leveling often practiced in Indian paddy farming. However, accurate laser land levelers have been created by integrating low-cost electronics, hydraulics and global positioning system (GPS) technology.

This paper provides an overview of current practices and suitable operating procedures to meet the future demand for land leveling. The presentation compares the laser land leveler with GPS land-leveling solutions, examining technical differences and individual merits and limitations. In addition, a stakeholder analysis evaluates the various technology solutions for agricultural practices.

Introduction

Of the world's available cropland, paddy accounts for more than 11%. It is imperative—for agricultural and environmental sustainability, food and water security and greenhouse gas emissions—that paddy rice agriculture is monitored and mapped in a timely and efficient manner. Meanwhile, water-resource management is a major concern because rice paddy is grown in flooded soils. More than 80% of the fresh water in most cases, and as much as 95% in some cases, is used for irrigation in the Asian study area. This degree of irrigation raises concerns about the maintenance and potential contamination of the water supply. Also, greenhouse-gas methane is a byproduct of seasonally flooded rice paddies, contributing to more than 10% of the total methane flux to the atmosphere.

In India, rice is grown over a large area and a broad range of landscapes; a wide variation of climatic conditions exist in such a varied landscape. Thus a variety of unique paddy farming techniques have evolved, based on water source (irrigated, rain-fed, deep-water), crop management (single-crop, multi-crop) and seasonality (wet season, dry season).

Flooding is required in paddy fields, so paddy crop uses large quantities of water, typically under flooded conditions. Improved water management assures high and stable productivity of rice, while weed growth also is reduced with flooding.

The average water requirement for growing rice with a stable water supply is around 220 gallons per kg of matter. Rice has some sensitivity to water stress and some tolerance to water excess. Therefore, the water condition of the rice paddy field should be well-controlled to maintain an adequate water supply and submerged condition.

Submergence of paddy fields by irrigation helps with the following factors:

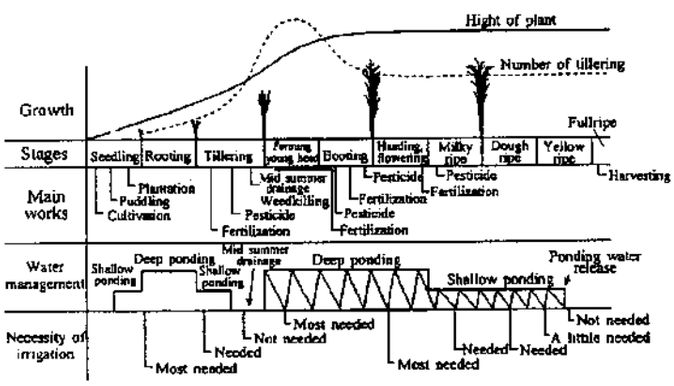


Figure 1: Rice growth, agricultural works and water management (Maruyama and Tanji, 1997).

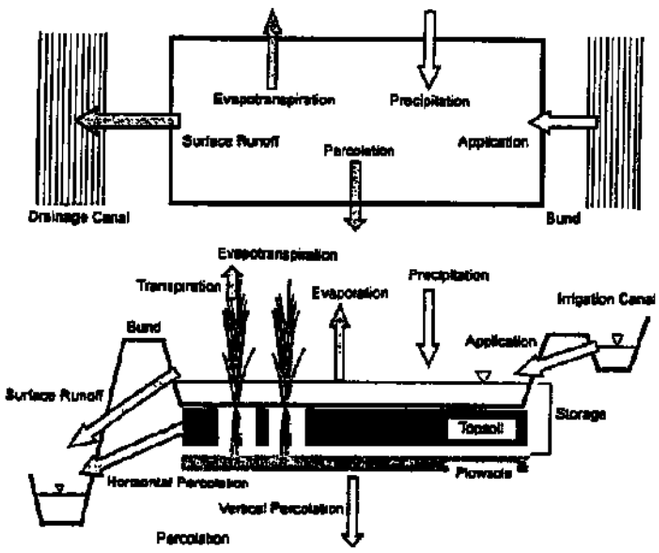


Figure 2: Schematic representation of the water budget in a paddy field plot (Watanabe, 1999)

Figure 3: The story of water in India (Columbia Water Centre)

- Stabilization of water supply to rice plants.
- Increased supplies of nitrogen and phosphorous and control of organic-matter dynamics.
- Supply of inorganic mineral salts contained in irrigation water.
- Weed control.
- Prevention of damage by blight, animals, insects and other living things.
- Maintaining temperature

The growth of rice plants can be divided into ten growth stages as shown in Figure 1.

The water-balance equation of a paddy filed can be expressed as follows: $R + Qi = ET + P + Qo + \Delta S$

Where R is precipitation, Qi is the irrigation water, ET is the evapotranspiration (consists of evaporation (E) from the water or ground surface and transpiration (T) from rice plants), P is the percolation (a balance of seepage away from the pond and ground-water intrusion form outside of the domain). Qo is surface runoff (includes runoff of excess rainfall which cannot be stored in the plot and spillage or drainage of water which has been applied or stored) and ΔS the change in storage.

(R + Qi) is usually expressed in units of water depth per day.

Figure 2 is a schematic representation of the elements in the water balance equation of a plot—and shows the importance of water depth per day across each plant. So there is a need to level the land to avoid uneven coverage of water across the field; if he field is leveled, water will cover the field and the depth of water (R + Qi) will be controlled, improving productivity.

In a nutshell: maintaining a constant depth for flooded water is important for both water conservation and maximizing productivity.

Row #	Customer Priority	Projects / John Deere Needs	Use of Tractor Valve	Use of Tractor Controller	Low cost receiver	Low cost transmitter	No Display unit	One Button	Beeper for operator interface	EH hitch position control	Reliability	Provision on tractor for Easy Integration
1	5	Low Cost	A	A	A	A	A	A	A	A	C	C
2	5	Leveling Accuracy should be high	A	B	A	A	C	C	C	A	C	C
3	3	Less number of Parts	C	C	C	C	B	C	C	C	C	C
4	3	Easy to use	C	B	C	C	B	C	C	C	C	C
5	2	No manual intervention for setting	C	C	A	A	B	C	C	C	C	C
6	1	Modular system	A	B	B	B	C	C	C	C	C	C
7	1	Year around aplicabilty of parts	B	B	C	C	C	C	C	A	C	C
8	2	Low cost parts	C	C	C	C	A	A	A	C	C	C
9	2	More working Range	C	C	A	A	C	C	C	C	C	C
10	4	Less movement of base station	C	C	C	A	C	C	C	C	C	C
11	4	Long Life	A	A	A	A	A	B	B	B	A	C
12	3	High End Technology	B	A	A	A	A	A	A	B	C	C
13	4	Enabler for other features i.e area measurement, auto surveying	C	A	A	A	C	C	B	C	B	B

Figure 4: Proposed solution QFD

Importance of land leveling

Higher yield

Good field leveling increases the rice yield considerably. In two experiments conducted at different localities, a strong correlation was found between the levelness of the land and crop yield.

Better weed control

Land leveling increases yield to a large extent because it improves weed control. Improved water coverage due to better land leveling reduces weeds by up to 40%. This reduction results in less time required for crop weeding; a reduction from 21 to five labor-days/hectare is achieved. This represents a reduction of up to 16 person-days/hectare–a 75% decrease in the labor required for weeding.

Larger farming area

Good land leveling enables larger fields. Larger fields increase the farming area and improve operational efficiency. Increasing field sizes from 0.1 hectare to 0.5 hectare increases the farming area by between 5% and 7%. This increase in farming area gives the farmer the option to reshape the farming area and can reduce operating times by 10% to 15%.

Faster seeding/ less work

Leveling reduces the time needed for transplanting and for direct seeding and provides greater opportunity to use direct seeding. The potential reduction in labor by changing from transplanting to direct seeding is approximately 30 person-days per hectare.

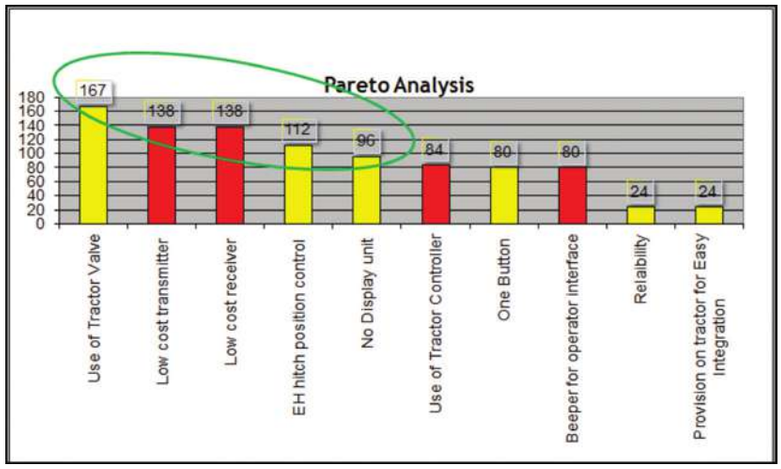


Figure 5: Pareto Chart

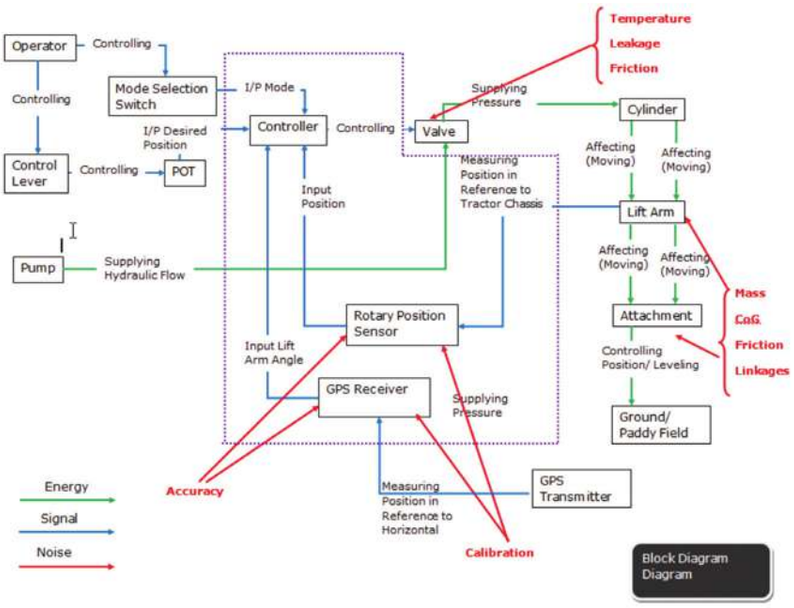


Figure 6: System block diagram with energy flow.

Better use of water

Rice farmers using animals or 2-wheel tractors rely on water to accumulate in the field before starting land preparation. The greater the difference between the highest and lowest portions of a rice field, the more water is needed to achieve complete water coverage. Good leveling may reduce total water requirement to grow the crop by up to 10%.

The story of water in India

Figure 3 shows the food/water/energy crisis in India. The increase in irrigation allowed India to provide more food for its population, but it also led to severe overexploitation of groundwater resources. Unchecked, depletion of groundwater at the current rate will have catastrophic consequences.

From the facts presented in Figure 3, it seems clear that for feeding millions, the nation needs more production of rice from the same field size. The country also needs to preserve water while keeping in mind the water requirements of the paddy fields.

Available technology for land leveling

By draft animals, such as buffalo and oxen, or 2-wheel tractors using harrows and leveling boards.

These leveling techniques require total water coverage of the field and require 7 to 8 days per hectare for a 2-wheeled tractor and 12 days using draft animals.

By a 4-wheel tractor using rear mounted tractor blades or drag buckets.

Four-wheel tractors are very effective for leveling both wet and dry fields. Wet fields are best leveled with a rear-mounted tractor blade. Dry fields are best leveled using hydraulically operated drag buckets. Tractor work rates are dependent on the tractor's capacity and the amount of soil to be moved. It takes approximately eight hours to level 1 hectare with a rear-mounted tractor blade. This is reduced to about four hours when using a drag bucket.

By a 4-wheel tractor with a laser-controlled bucket.

The use of laser controlled equipment results in a much more level field—up to 50% better than leveling using other techniques.

Laser leveling systems are commonly used in agricultural applications in Australia, Japan and the United States. Increasingly, laser-guided systems are being used in lesser-developed countries as well. Using laser leveling results in a much more level field because accuracy can be improved by as much as 50% compared with the other systems.

A laser transmitter projects a beam which is intercepted by the receiver mounted on the leveling bucket. The control panel mounted on the tractor interprets the signal from the receiver and adjusts the leveling bucket, making the entire field level. More-costly GPS-based leveling systems are being used in the U.S. and Australia, but these systems are not affordable for the Indian environment. The GPS system is, however, more capable and accurate than laser land levelers.

Drawbacks of available technology for land leveling

- High operation costs.
- Skilled operator required.
- Weather limitations (cannot work in dusty or rainy conditions, sacrificing productivity).
- Range coverage: every 300 m there is a

change in earth curvature, which impacts laser land-leveling accuracy.
- More component complexity.
- Requires installation of accessories.
- Alteration of tractor required to integrate laser land levelers.
- Equipment installation requires time.
- Laser land levelers limited to seasonal use.
- Pre-surveying and manual calculations required for laser land levelers.
- Pre-surveying equipment required.
- High degree of manual intervention to adjust the laser transmitter and receiver.

Defining proposed solution architecture

A new, low-cost leveling system using GPS technology is proposed. The primary requirements from the customer are captured through quality function deployment (QFD) and related with the functional requirements of tractor systems. The QFD matrix is shown in Figure 4.

With the QFD, a Pareto chart (Figure 5) is generated to identify the top 3-5 unmet customer requirements.

The concept in Figure 6 was generated to meet the top customer requirements.

Lab experimental details

A vital few control parameters were identified to derive the performance correlation of the system. A DOE was designed and transfer function developed.

A main effect and interaction plot was generated to see the effect of each variable on system performances and system performance was optimized.

Filed validation details

An accuracy of ± 2 cm in both the fields was obtained. This could reduce the water flooding cost for the farmer and translate into a water irrigation saving of Rs 200 per acre.

To validate the consistency of the system this was repeated again in a second plot.

Comparision of proposed solution with existing solutions

- Saving of field operation time: 17 minutes.
- Using I-rod requires 24 +6 = 30 minutes for median calculation; setting prior to actual operation avoided.
- In case of operation as per operator judgment, 10 mins required for initial setting before operation.
- Laser leveling (as per I-rod median value) requires 1 driver plus two laborers.

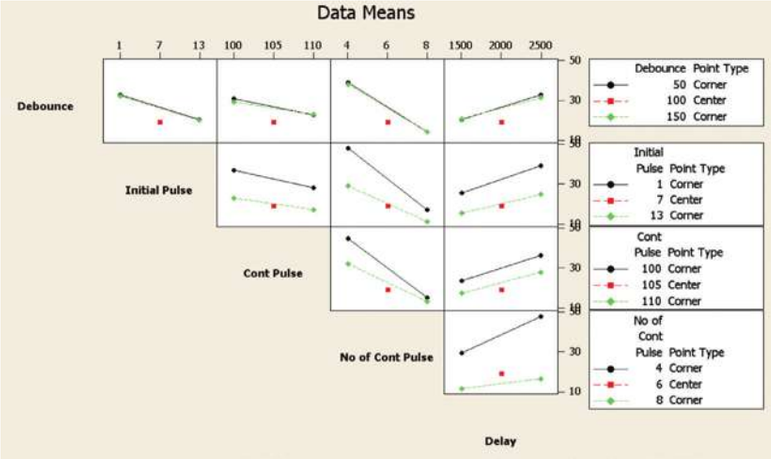


Figure 7. Interaction plot for vital few control variables.

Readings before GPS Land Leveling | Readings after GPS Leveling

Plot 1

Previous Operation- 2 Pass Cultivator & leveling by operator's judgement

Field measurement calculation period = 6 mins.
Field operation total period = 1:54 hrs.
Total field area coverage =0.9 Acre

Set	I(cm)	II(cm)	III(cm)	IV(cm)		Set	I(cm)	II(cm)	III(cm)	IV(cm)
	142	140	132	135			147	146.5	146	146.5
	145	139	140	143			146	146	146.5	145.5
	144	143	147	144			146	146.5	145.5	146
	148	145	145	151			145.5	146	146	147
	152	151	149	149			146	146.5	145	145.5
	145	146	150	150			146.5	145.5	146	146
	148	147	152	148			147	146.5	146.5	147.5
	1024	1011	1015	1020	Total		1024	1023.5	1021.5	1024
			28 Points total	4070					28 Points total	4093
			Average =	145.36					Average =	146.18
			Max Difference	13.36					Max Difference	1.18
			Min Difference	-6.64					Min Difference	-1.32

Figure 8: Before and after readings across plot 1.

- Laser leveling (as per judgment) requires one driver plus one laborer.
- With use of common parts from the tractor (i.e. EH valve), the controller and operator interface provided operator comfort and facilitated easy integration and removal of the GPS system.
- Use of a low-cost GPS transmitter and receiver to maintain the same accuracy as a laser land leveler provided a low-cost solution for the Indian farmer.
- A user-friendly operator interface required less modification of the tractor and improved productivity.
- The proposed system saved considerable time typically required for manual adjustment of the laser receiver.
- The proposed system provided features to determine the contour of the field before and after land leveling, a helpful freature for farmer and contractor.

Stakeholder analysis

Current Stakeholder Scenario

The supply ranking represents the importance of a particular stakeholder in delivering value. The benefit ranking shows the importance of value to stakeholder.

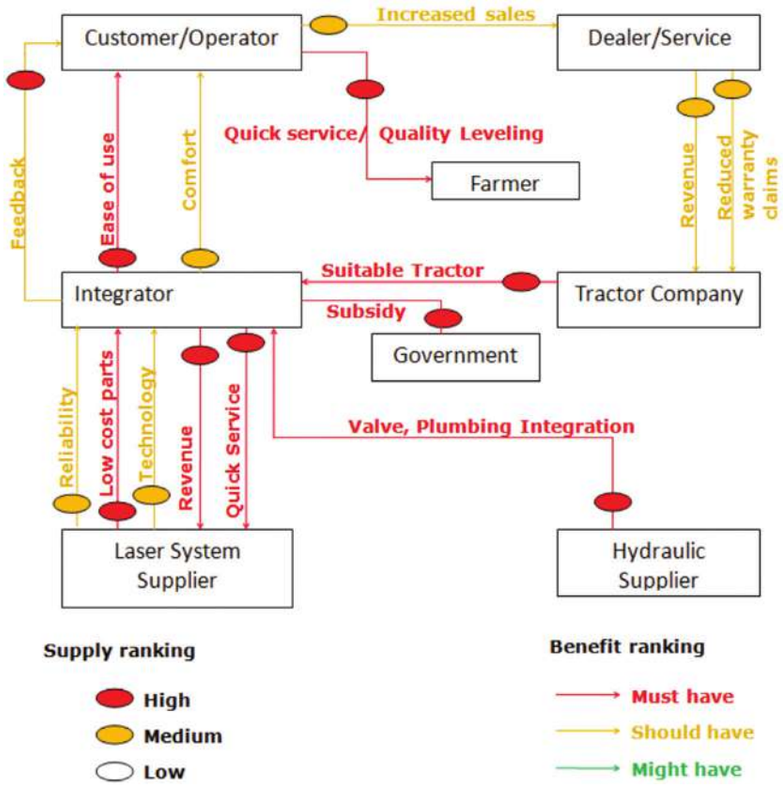


Figure 9: Stake holder analysis for existing solution

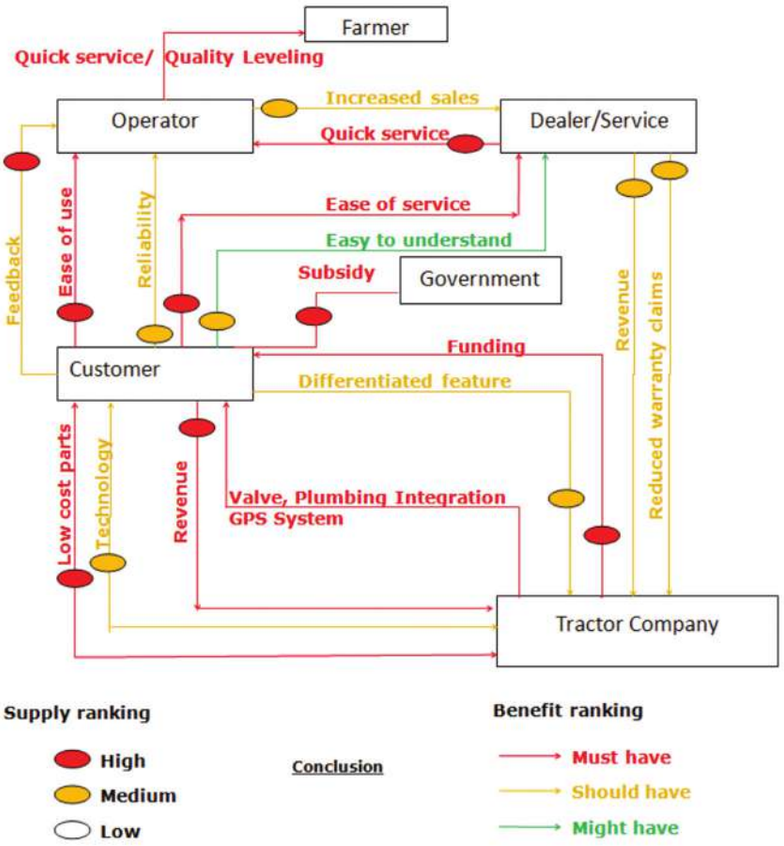


Figure 10: Stake holder analysis for proposed solution

Proposed System Stakeholder Scenario

Intermediate stakeholders such as the laser-system supplier, the hydraulic supplier and integrator are removed—the customer can purchase the system directly from the company and the dealer network can be effectively utilized for service support.

Summary/conclusions

Key Results

- Saving in field operation time for 1-acre field: 47 minutes.
- Improved operator comfort by 20%. Previously, the operator could work for eight hours; with the proposed system, the operator could work for 10 hours.
- No extra EH valve, controller and plumbing: 30% to 40% system-cost saving.
- Many common parts.
- Year-round applicability.
- Low cost.
- Every top-five requirement, as identified in QFD, met with the proposed system.

How much better?

- Leveling accuracy on par with laser-leveling system.
- Cheaper by 30% to 40 % compared with present available solutions; cost makes this technology available to all, not limited to one class or contractor.
- Use of GPS technology for water preservation will aid growth of sustainable agriculture.
- Quality maintenance and reliability of the system is improved. There is a single point for servicing all the subsystems.
- More farmers can afford the system, improving water-use efficiency in the field.

Key Limitations

As the proposed low-cost GPS land leveling has shown promising results in the topographically difficult terrain of India—where the soils have high gravel content, low organic matter and issues related to slope—the agricultural extension agencies should promote this technology in the irrigated areas of north and south India. The government might, however, need to facilitate soft loans and other credit facilities for cash-short farmers in India to help expand application of the technology. ■

Authors: Mr. Saurabh Gupta, Off Road Engineering SL; Mr. Robesh Maity Sr. and Mr. Shrirang Kulkarani, CEng., John Deere India Private Ltd.

Rotorcraft Icing Computational Tool Development

A CH-47 Chinook helicopter raises a white out of blowing snow as it lands at a remote landing zone in Shah Joy district, Zabul province, Afghanistan, Feb. 8. Helicopters provide an efficient and reliable means of transporting personnel and cargo to rural areas of Afghanistan. (Photo courtesy U.S. Army)

The formation of ice over lifting surfaces can affect aerodynamic performance. In the case of helicopters, this loss in lift and the increase in sectional drag forces will have a dramatic effect on vehicle performance. The simulation of rotorcraft flow fields is a challenging multidisciplinary problem that lags in development over its counterpart in the fixed wing world by more than a decade. Successful aerodynamic simulation of a rotor/fuselage system requires the modeling of unsteady three-dimensional flows that include transonic shocks, dynamic stall with boundary layer separation, vortical wakes, blade/wake and wake/wake interactions, rigid body motion, blade deformations and the loss of performance caused by ice accretion.

Stand-alone ice accretion prediction tools, as well as ice accretion fully integrated with aerodynamics, currently exist for 2D airfoils and 3D aircraft configurations. Ice accretion predictions are typically two-dimensional in nature and based on the classical Messinger model. The analysis consists of four critical steps: flowfield calculation, water droplet impingement calculation, heat transfer prediction, and ice accumulation normal to the surface.

LEWICE and LEWICE3D

LEWICE is NASA's flagship code for 2D ice accretion prediction, and it is the core of the 3D ice accretion tools as well. LEWICE development was initiated in the early 1980s, with the first general release (Version 1.0) in 1991. Four major updates to the code followed, in 1993 (Version 1.3), 1995 (Version 1.6), 1999 (Version 2.0) and 2002 (Version 2.2). Recent updates were released in 2005 (Version 3.0) and 2006 (Version 3.2), and a mixed-phase modeling capability was added in 2008.

The code uses a potential panel method to determine the flow field about a clean surface, then calculates water droplet trajectories from some upstream location until they impact the surface or until the body is bypassed. Collection efficiency is then determined from the water droplet impact location pattern between the impingement limits. A quasi-steady analysis of the control volume mass and energy balance is performed next using a time-stepping routine. Density correlations are used to convert ice growth mass into volume. LEWICE also features multiple drop size distributions, multiple airfoil elements, thermal models for anti-icing/de-icing systems, and an interface with structured grid codes, allowing the use of viscous Navier-Stokes flow solutions.

The thermal models in LEWICE combine the features of previous codes, LEWICE/Thermal and ANTICE, to simulate de-icing and anti-icing with electrothermal or hot air systems. Features are included to allow determination of optimized heater sequencing (for electrothermal analysis) and multiple boundary conditions (for bleed air analysis).

LEWICE has been thoroughly validated for a wide range of conditions, with a database of over 3,000 ice shapes on 9 different geometries. Validation has been documented in numerous papers as well as

Rotorcraft Icing Computational Tool Development

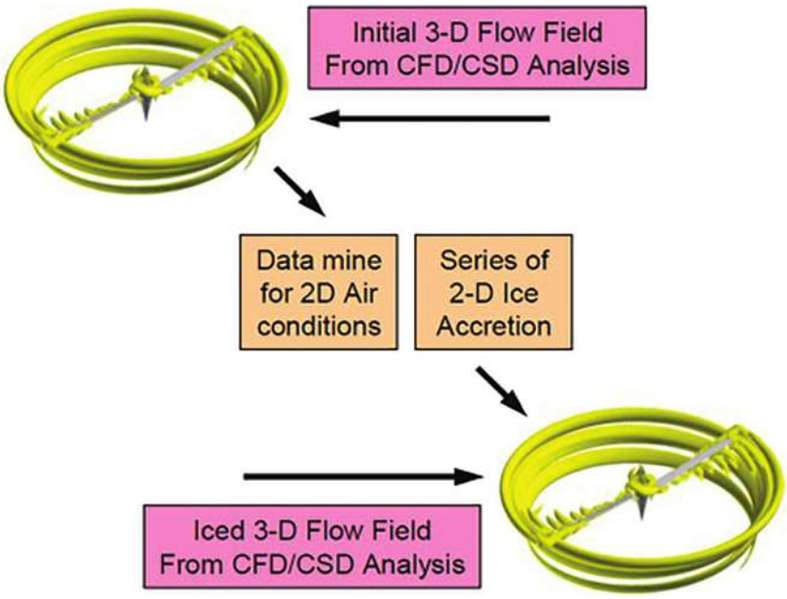


Figure 1. Methodology for developing a 3D ice shape.

NASA reports. The validation database lies mostly within the Appendix C continuous maximum or intermittent maximum envelopes, but there are some exceedance and super-cooled large droplet conditions for comparison as well. This validation, along with significant research into recommended test methods and advanced component models, has led to a degree of acceptance for use in reducing the cost of development and certification programs.

However, this acceptance does not exist for rotary-wing applications.

LEWICE does not simulate a fully rotational system, but does allow the user to input a number of simple parameters-distance from the hub to the 2D section of interest, rotation speed, and orientation of the plane of rotation (vertical for propellers, horizontal for rotors). LEWICE performs three additional calculations in rotating body cases. The rotation speed is used to calculate an increase in the aerodynamic heating term in the energy balance, the rotational force is included in the ice shedding determination, and the rotational force is used to find the resultant force of the shed ice particle, which is then used to track the particle after it is shed. The rotating body information is not used by the potential flow solver in LEWICE, nor is the rotating body information used by the trajectory equation.

LEWICE3D is a suite of codes, developed by **NASA** and used widely by industry, to determine the amount and location of ice accretion on an aircraft. It is used to calculate water loading on aircraft surfaces so that the size and location of ice protection systems can be determined, to optimize the placement of icing sensors, and to determine ice shapes used in failed ice protection system tests. It is also used to determine corrections for cloud measurement instruments, such as droplet size probes or liquid water content probes on NASA research aircraft.

LEWICE3D uses a Monte Carlo-based collection efficiency calculation using droplet impact counts. Trajectories are calculated using an Adams-type predictor-corrector method. Tangent trajectories and collection efficiencies for simple 2D or 3D regions can also be calculated using a modified version of the 2D LEWICE method. Streamlines are calculated using a 4th-order Runge-Kutta integration scheme.

The ice growth methodology in LEWICE3D uses a single time step strip approach and requires a steady or time-averaged flow solution, supplied by the user. The strip approach is based on the classical Messinger energy balance procedure with an integral boundary layer technique used to generate heat transfer coefficients, and is a modified version of the method used in the 2D LEWICE code applied along streamlines. LEWICE3D supports multi-block structured grids, adaptive Cartesian grids and unstructured grids, as well as panel- based binary-tree grids.

LEWICE3D includes extensions which allow generation of a full 3D ice accretion for surfaces and generation of a new iced surface, calculation of off-body concentration factors, and determination of shadow zones. The program has been parallelized using OpenMP and MPI (message passing interface) to complete jobs faster on parallel machines. The parallel version has been ported to **SGI** and **Linux** machines.

However, the current NASA icing codes, LEWICE and LEWICE3D, cannot be applied directly to the ice accretion of rotorcraft flows for several reasons. These codes are acceptable for the majority of fixed-wing applications, such as general aviation, business jets or commercial transports, but there are still shortcomings for some vehicle types, notably rotorcraft.

Past research in rotorcraft icing codes

The importance of rotorcraft airfoil oscillation during ice accretion was recognized in the early 1980s and NASA sponsored an icing wind tunnel test of a 2D six-inch chord oscillating airfoil. This **Sikorsky**-run test confirmed that the variation in angle of attack altered the ice shape and produced changes in the drag coefficient. About this same period of time, Sikorsky and the **United Technologies** Research Center designed, fabricated, and tested in dry air 2D and 3D models with a chord of 17 inches. Meanwhile, as part of an earlier project, Sikorsky designed and fabricated an airfoil test rig to span the NASA Icing Research Tunnel (IRT) test section. This apparatus had a chord of 15 inches and mounted to the upper and lower IRT turntable. Maximum angle of attack for the airfoil was 10 degrees at the maximum operating speed of the IRT of 250 knots (with the model installed and with ice on the model leading edge), with an angle of attack of at least 20 degrees at 150 knots in the IRT.

To further research on rotorcraft icing, a Government-industry consortium, composed of NASA, **Texas A&M University**, **Bell**

Helicopter Textron, **Boeing Helicopters**, **McDonnell Douglas Helicopters**, and **Sikorsky Aircraft**, was created to better understand the impact of rotor blades ice accumulation on aircraft performance, increase in vibration and ice shedding. The program was to also validate the industry existing performance models and assessed the benefits of rotor blade scaled model testing.

A two-model approach was selected as the most effective means to accomplish the program goals. A lightly instrumented OH-58 tail rotor that had been modified to operate as a main rotor was chosen as the initial test article.

The initial experimental program was conducted in 1988 in the NASA Lewis Research Center Icing Research Tunnel in which the OH-58 tail rotor assembly was operated in a horizontal plane to simulate the action of a typical main rotor. Ice was accreted on the blades in a variety of rotor and tunnel operating conditions and documentation of the resulting shapes was performed. Rotor torque and vibration were recorded and presented as functions of time for several representative test runs, and the effects of various parametric variations on the blade ice shapes were shown. This OH-58 test was the first of its kind in the United States.

Based on the results of these two tests, it was clear that the CFD methods developed during future studies must include airfoil oscillation and that data must be acquired to validate the method(s). Although investigations into rotor blade ice protection systems continued 1997-99, and commercial use of the IRT continued, NASA essentially put rotorcraft icing research on hold in 1994 to focus on fixed wing following a highly visible fixed-wing accident.

Progress in tool development

When opportunity finally arose again at NASA in 2004-2005, the state-of-the-art of subsonic rotary wing icing was quasi-steady and quasi-3D. Grid generation for complex icing shapes was 2D and interactive or crudely automated. There could be a variously loose coupling between the aerodynamics and the ice accretion-but not yet a true, multi-phase solution.

The icing analysis procedure for prediction of performance degradation must address both aerodynamic performance and ice accretion. Aerodynamic performance degradation involves the calculation of the aerodynamic coefficients of the iced geometry. The section lift, drag and moment characteristics

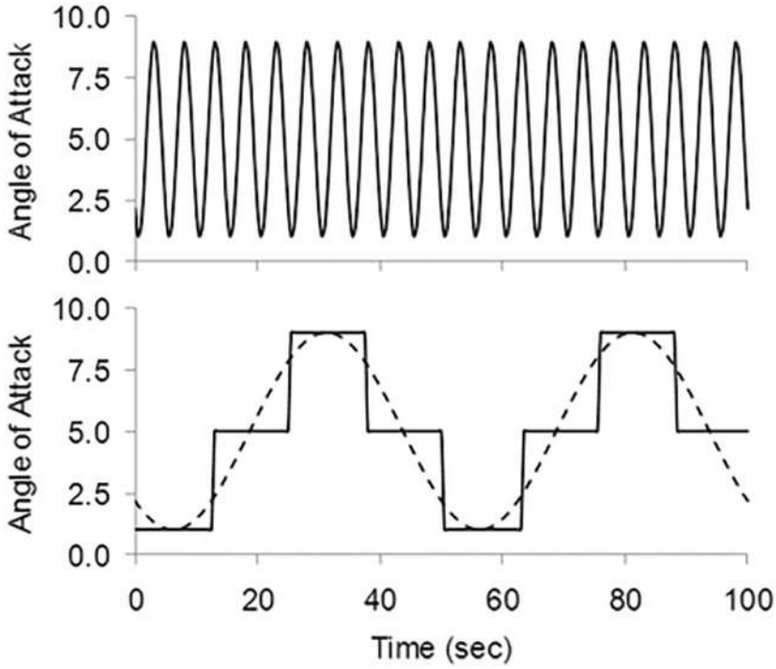


Figure 2. Approach for simulating oscillation of rotor.

with ice must be accurately known in order to predict the performance degradation from an icing encounter. Lifting line theory is one commonly used method, but momentum source methods coupled with blade element theory are also widely used, as are panel methods. Often, proprietary methods or Navier-Stokes solvers are used to calculate aerodynamics.

NASA's objective was a robust, validated coupling of a rotor performance code with an ice accretion code. The CFD analysis of a clean rotorcraft configuration is well within the range of current technology. Fully time accurate simulations of ice accretion on rotorcraft blades are not currently feasible, however. The complexity of the problem demands high-fidelity tools based on first principles, and a tightly-coupled, physics-based approach is not currently available.

Rotorcraft aeromechanical studies involve coupling the rotor aerodynamics with the structural dynamics of the system. The airloads computed by the CFD solver is used to drive a forced response simulation with the CSD solver. The computed structural deflections are used in the CFD analysis, leading to a change in the airloads. The two solvers are thus inherently coupled. The CFD-CSD coupling may be performed primarily in two ways—loose and tight. In tight coupling, the data is exchanged every time step of the simulation. In loose coupling, the data is exchanged between the two solvers at periodic intervals, typically once per revolution. Since loose coupling is driven by the inherent periodicity in the solution, it is used for analysis of rotors in steady flight conditions.

Coupling ice accretion models with aeromechanics

One successful approach is an integrated tool set capable of modeling ice accretion and the overall effects of rotor performance. This loosely coupled suite of tools (LEWICE, GT-Hybrid, and DYMORE) has been applied to a representative rotor for detailed study. The entire process (clean rotor grid generation, clean rotor analysis, ice accretion simulations, and iced rotor analysis) is automated and modular. NASA entered

Rotorcraft Icing Computational Tool Development

Model rotor in the Icing Research Tunnel.

into a two-year cooperative agreement with the Georgia Institute of Technology, to develop improved coupling techniques for icing computational fluid dynamics. Georgia Tech was partnered with the Sikorsky Aircraft Corporation.

The project utilizes a 3-D Navier-Stokes analysis and a multi-body dynamics tool, coupled with the GT-Hybrid unstructured Cartesian grid-based flow solver to represent the ice shapes. Several different Navier-Stokes flow solvers have been used in this framework including OVERFLOW, TURNS, and GT-Hybrid. GT-Hybrid, a three-dimensional unsteady viscous compressible flow solver that uses a free wake solver to model the effects of the rotor wake. The flow is modeled from first-principles using the Navier-Stokes methodology. The three-dimensional unsteady Navier-Stokes equations are solved in the transformed body-fitted coordinate system using a time-accurate, finite volume scheme. A third-order spatially accurate Roe scheme is used for computing the inviscid fluxes and second order central differencing scheme for viscous terms. The Navier-Stokes equations are integrated in time by means of an approximate implicit time marching scheme. A Spalart-Allmaras turbulence model is used to compute the eddy viscosity. The flow is assumed to be turbulent everywhere, and hence no transition model is currently used.

A single blade is resolved in the Navier-Stokes domain. The influence of the other blades and of the trailing vorticity in the far field wake is accounted for by modeling them as a collection of piece-wise linear bound and trailing vortex elements. The near wake is captured inherently in the Navier-Stokes analysis. The use of such a hybrid Navier-Stokes/vortex modeling method allows for an accurate and economical modeling of viscous features near the blades, and an accurate "non-diffusive" modeling of the trailing wake in the far field.

Coupled CFD/CSD analysis for rotorcraft in forward flight

Another icing analysis process that has been developed involves the loose coupling of OVERFLOW-RCAS for rotor performance prediction with LEWICE3D for thermal analysis and ice accretion. This method uses three-dimensional analysis for rotor performance and degradation and two-dimensional analysis for ice accretion. The automated process allows for rapid analysis in a parametric study or for the analysis of an airfoil subject to the many conditions existing on a rotor. For validation, predictions of performance and ice shapes were compared with experimental data for rotors in hover and in forward flight.

NASA entered into a two-year contract with the Boeing Company (Ridley Park, PA), to develop these improved coupling techniques for icing computational fluid dynamics. The project resulted in a process by which OVERFLOW, RCAS and LEWICE can be loosely coupled to assess ice accumulation and rotor performance degradation for helicopters in forward flight, as shown in Figure 1. The system has been tested and evaluated using existing wind tunnel or flight data, and effort is still ongoing. The result is a computational approach for performing high fidelity simulations with ice accretion of rotorcraft blades. The approach is appropriate to address ice accumulation on rotors in flight regimes from hover to high-speed forward flight.

The high fidelity icing analysis approach developed for rotor systems follows three basic steps:

- Establish rotor trim, clean rotor performance and the initial flow field environment using CFD or coupled CFD-CSD as appropriate;
- Extract representative 2D airfoil conditions for blade sections at radial and azimuthal locations and predict ice buildup on the rotor accounting for the diverse operating environment of the rotor;
- Reestablish rotor trim and performance for the iced blades.

Rotor blades experience pitch oscillations as they rotate around the shaft. Pitch oscillations introduce time varying conditions that influence the distribution of ice along the leading edge. The process to predict ice on an oscillating airfoil is built on the premise that the shape is not a strong function of the frequency of the oscillation and is predominantly influenced by the mean and amplitude of the pitch variation. With this assumption, the time history of an oscillating airfoil can be represented by a very slow moving blade. Furthermore, if we assume the shape can be approximated by only considering the mean angle of attack and the extreme excursions from the mean, the blade motion can be represented as the series of quasi-static events, as shown in Figure 2.

Once the ice has been established on the

blade, the CFD-CSD analysis process is repeated for the iced rotor. The 3D rotor grid is modified to account for the ice shape on the blade. The input to the CSD analysis is also modified. Accreted ice adds to the blade section mass and chordwise inertia. It is assumed that accreted ice has no effect on stiffness properties. The mass of ice is determined from post-processing the icing analysis, and the placement of the ice is assumed to be at the section leading edge. Updates to the section mass, center of gravity offset, and chordwise inertia are computed and used in RCAS. Rotor performance degradation is obtained by comparing the forward flight performance characteristics of the iced rotor to the baseline rotor.

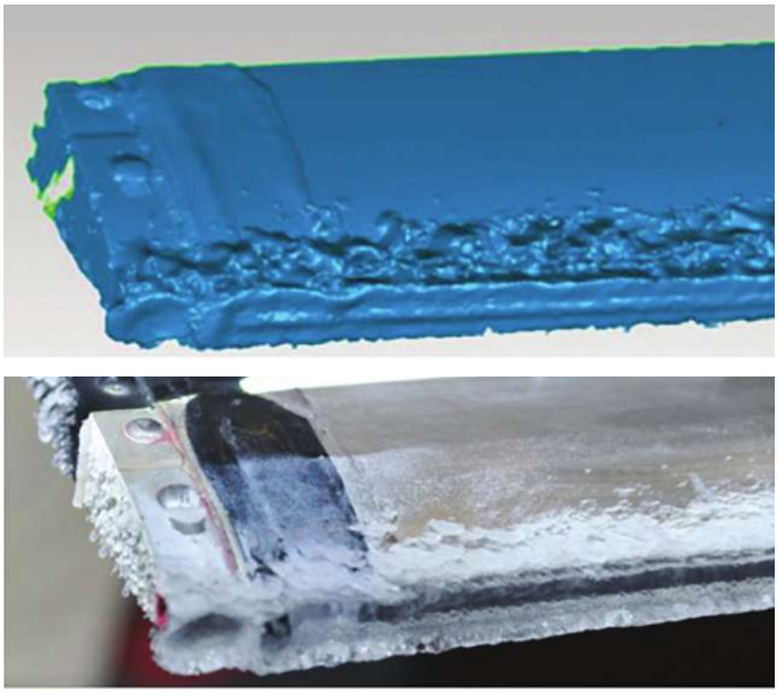
High-resolution CFD analysis of rotorcraft icing

Additionally, various Eulerian approaches (with both one-way and two-way coupling) for simulating ice accretion have also been examined, but significant work is still required in order to fully demonstrate this alternate method. NASA entered into a two-year cooperative agreement with the Pennsylvania State University to develop improved coupling techniques for icing computational fluid dynamics. Penn State partnered with Bell Helicopter Textron, Inc.

The project applied a zonal approach to the unstructured FUN3D flow solver, extended the existing NASA LEWICE ice accretion formulation to the rotorcraft environment, and coupled this module with the outer CFD flow solution. Initial validation will be conducted by comparison with existing test data. The work will result in an advanced software tool for performing high fidelity CFD simulations with ice accretion of rotorcraft blades. Work is currently ongoing on the thermal modeling for generalized rotorcraft flows, although some issues include the computation of recovery temperature with variable stagnation conditions, transitional flow effects, and working out details to handle them with access to a limited amount of data.

Conclusions

An integrated tool set capable of modeling ice accretion and the overall effects of rotor performance was developed and demonstrated. Key computational parameters were explored, and preliminary results for cases of practical interest were encouraging. Modifications to LEWICE were demonstrated which allow for the retention of previous time-step ice shapes.



Comparison between scanned data (top) and photograph (bottom) of ice shape on a rotor blade.

Preliminary development of a three-dimensional Eulerian analysis for modeling droplet impingement was also undertaken, to improve more efficient calculation of collection efficiency. The development of a tightly-coupled truly multi-physics approach is still a goal to work towards, but several promising efforts have been undertaken recently. Additional effort is still needed to improve methods for predicting rotor blade shedding and de-icing/anti-icing system performance. An icing analysis process involving the loose coupling of OVERFLOW-RCAS for rotor performance prediction with LEWICE3D for thermal analysis and ice accretion was developed and demonstrated. The method uses 3D analysis for rotor performance and 2D analysis for ice accretion. For validation, predictions of performance and ice shapes were compared with experimental data for rotors in hover and in forward flight.

Studies have also been conducted to examine the effects of grid spacing, grid density, turbulence model, flow-field update frequency and number of spanwise cuts, to name a few. Likewise, simulations of ice accretion prediction and associated rotor performance degradation have been conducted for multiple 2D airfoils and for various 3D rotors in hover and in forward flight. Ice accretion and detailed aerodynamic measurements for 2D clean and oscillating airfoils undergoing both steady and transient behavior was obtained in the IRT. Ice accretion, rotor performance and de-icing/anti-icing system behavior was obtained for a 3D rotating tail rotor in the IRT. For the first time the coupling of an icing code with a computational fluid dynamics code and a rotorcraft structural dynamics code has been demonstrated. The codes and research conducted here are already being transitioned and used by industry. ■

This article is based on SAE Technical paper 2015-01-2088 by Richard E. Kreeger, NASA John Glenn Research Center; Lakshmi Sankar, Georgia Institute of Technology; Robert Narducci, Boeing Co.; and Robert Kunz, Penn State University, doi:10.4271/2015-01-2088.

3D PRINTING MACHINES can't be built fast enough

The Department of Energy's Manufacturing Demonstration Facility at ORNL is now home to the world's largest polymer 3D printer. The new BAAM (Big Area Additive Manufacturing) machine is another result of ORNL's yearlong collaboration with Cincinnati Inc.

In the additive manufacturing world, the costs of components are dropping, the technology is becoming more reliable and parts are fabricated faster, allowing industries beyond aerospace to adopt additive technologies, says Oak Ridge Lab's Ryan Dehoff.

by Matthew Monaghan

As Deposition Science and Technology Group Leader at **Oak Ridge National Laboratory** (ORNL), Ryan Dehoff facilitates the development of additive manufacturing of components, utilizing various techniques including electron beam melting, laser metal deposition and ultrasonic additive manufacturing. He is developing processing techniques and exploring new materials via additive manufacturing to improve energy efficiency during component production, decrease material waste and improve material performance. We recently spoke with Dehoff to learn more about these innovations and industry trends.

What are some of the new applications where additive manufacturing could potentially be used?

A couple of examples I've seen in the automotive industry are things like utilization of metal powder bed systems to make injection mold tooling. That's a really big application for additive manufacturing because you don't necessarily have to certify and qualify an end-use part, but it can dramatically increase the cycle time of injection molded components and therefore lead to decreased cost of producing that component. People are also looking at utilizing additive technologies to build

"The big challenge with additive is it may be difficult to actually qualify and certify parts with a conventional mind-set," said Ryan Dehoff of Oak Ridge National Laboratory.

Big-time 3D printing: building an excavator, layer by layer

3D printing a car is impressive enough; building an excavator, layer by layer, is downright unimaginable. Researchers at **Oak Ridge National Laboratory** (ORNL) have not only imagined it, they plan to execute it next spring at ConExpo/Con-Agg in Las Vegas with a live demonstration.

Some off-highway companies took notice of what ORNL did with **Cincinnati Inc.** and **Local Motors** on the 3D-printed car (see http://articles.sae.org/13841/)—and wanted to go bigger, Lonnie Love, group leader for manufacturing systems research and corporate fellow at ORNL, explained to *Off-Highway Engineering*. "They wanted to do something similar in terms of demonstrating something grand that could get people excited about where additive manufacturing and construction is going. That was the catalyst for pursuing this vision of printing an excavator at ConExpo."

ORNL is teaming with several organizations to bring this vision to reality. Key partners on the 3D-printed excavator project include the **Association of Equipment Manufacturers**, the **National Fluid Power Association**, the **Center for Compact and Efficient Fluid Power** and the **National Science Foundation**. OEMs like **Case New Holland** and universities, including the **University of Minnesota**, are also contributing to the project, which is supported by the **U.S. Department of Energy**'s Office of Energy Efficiency and Renewable Energy – Advanced Manufacturing Office.

Components of the world's first 3D-printed excavator will be developed using the Wolf Robotics system installed at the Dept. of Energy's Manufacturing Demonstration Facility at ORNL. Actual printing has not yet begun. (Photo courtesy of ORNL, Dept. of Energy)

Additive Manufacturing webinar

Additive manufacturing is gaining steam in the automotive industry, and not just for prototyping parts. 3D printing processes increasingly are being evaluated for production components, with their promise of shorter development times, lower tooling costs, parts consolidation, more dramatic part shapes and sizes, among other benefits. During this free one-hour **SAE** Technical Webinar, scheduled for late September, experts will discuss these benefits as well as implementation challenges, detail current additive-manufacturing technologies and applications, and offer a vision for what the future could hold for 3D-printed parts in production vehicles. To register, visit www.sae.org/webcasts. Sponsor: **Stratasys**

prototype engines that they might want to go into production in the future. So they're trying to make those engines more efficient and more cost-effective through design optimization, and additive gives them a valuable tool to be able to go through and look at those designs prior to going into the casting or production process.

Where is the 3D printing standards discussion at currently?
The standards that are being developed, I think, are a good first step in implementation of additive into different industrial applications. But I think the big challenge with additive is it may be difficult to actually qualify and certify parts with a conventional mind-set. There are a lot of different groups; I know there are several different standards organizations and they all have efforts in additive manufacturing ongoing. Some of the government standards organizations also have some fairly large efforts going on in how to certify and qualify additive. It would be good to make sure as we go through and start trying to develop those standards that it's not only the aerospace community that's involved in standards development, but it's also automotive and other industrial sectors that are also involved with that development work.

How do you see the automotive industry embracing additive manufacturing?
There's a lot going on behind the scenes that a lot of people aren't necessarily talking about. Because it does have the potential to revolutionize people's business cases. Right now, most of the additive manufacturing are niche applications, especially in the automotive industry. We have a tendency for additive parts to focus on customization. An example of the potential for customization is something like Jay Rogers from **Local Motors**, and what he's trying to do is make a micro-factory where you may come in and design your car. At the same time, we see that going down into mass customization for the tool and die industry where you can start getting into very low-volume production as well, which is a little bit unique and a niche market. Eventually it may be adopted well beyond that also.

Is the aerospace industry much farther along in terms of adopting additive manufacturing?
The general trend that I've seen in the industry over the past decade is that aerospace seemed to be the main driver because it had huge payoffs associated with making components lighter and making components more efficient. What we're starting to see in the additive world is that the costs of components are dropping, the technology is becoming more reliable, you can get parts fabricated faster and that's allowing different industries to adopt additive technologies like the auto industry. There are some unique things that I know **Cummins** has done where they've been able to increase the efficiency of their engine through additive technologies. I don't know if it's being bulk adopted for 3D printing of car frames or bumpers; that's probably not where we're going to be any time soon, but on specific applications in turbochargers,

3D PRINTING MACHINES can't be built fast enough

At the Manufacturing Demonstration Facility at ORNL, about 15 people, consisting of material scientists, engineers and mathematicians, are working on the project. "We have a core group that's looking at the next generation of large-scale 3D printers. A lot of work has gone on in terms of polymers and composites; now we're going toward large-scale metal," Love said.

There are three elements of the 3D-printed excavator, each created through different additive processes: a composite cab using Cincinnati's Big Area Additive Manufacturing (BAAM) system, a metal heat exchanger manufactured using the **Concept Laser** powder bed system, and a metal boom born of a large-scale metal printer that's still under development with **Wolf Robotics**.

"So in one demonstration, you really get a strong glimpse of where the technology's going," he said.

"We're going to try to print out a heat exchanger that will actually be functional and shows the limits of what you can do with additive in terms of increasing the [exchanger's] efficiency as well as making it lighter and smaller," said Love. The laser system enables very fine detail and high accuracy.

The biggest part and the most challenging, according to Love, will be the boom. The plan is to have the Wolf robotic system "growing" large metal parts at a fairly high rate within nine months. "I've been at Oak Ridge for about 20 years and this is by far, for me personally, the biggest challenge my team has tackled. It's a big leap, but I have full confidence in the team including all of the industrial partners," he said.

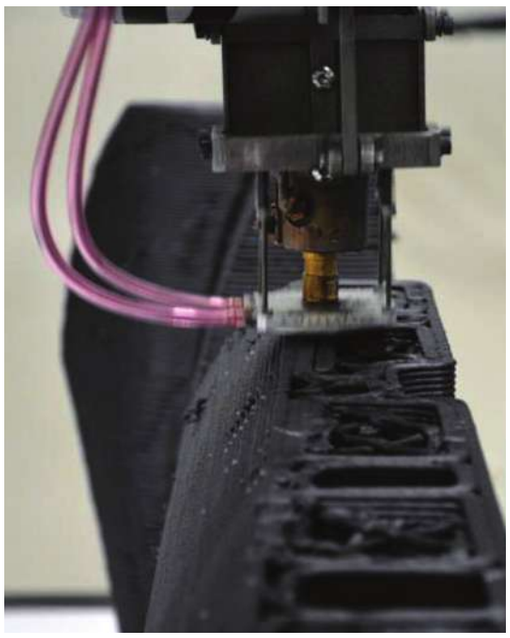
The printer will be smaller than the BAAM polymer system, which in terms of build volume is 8-ft wide, 6-ft tall and 20-ft long. The Wolf metal printer will be in the range of 4 x 4 x 10 ft, Love said.

ORNL is trying to overcome factors that have traditionally hindered the progress of metal printers—namely size, speed and cost of materials. "With metal printers, we're primarily making things that are about a cubic foot in volume at rates of about one cubic inch of material grown per hour," Love explained. "So to make something the size of a coffee cup will take you all day. And the materials are generally very expensive, hundreds of dollars a pound. That really is restrictive. So we're trying to use low-cost feedstock steel that's about a dollar per pound and trying to grow parts at relatively high rates—hundreds to thousands of cubic inches an hour. If you do that, then it starts to become compelling in terms of using additive for things like excavators."

Off-highway industries such as construction, with its relatively low volumes especially compared to passenger vehicles, is in the range where additive can be a powerful tool, if the technology progresses the way Love and others at ORNL envision.

"That's part of our focus at Oak Ridge," said Love, "how to enable these technologies to open up capabilities that are attractive for industries that, up until today, haven't been interested."

Ryan Gehm



BAAM system extruder.

water pumps and engine housings, those types of things may be a reality sooner than we think.

What are some of the materials being considered for additive?

Holistically, most of the materials that are being developed are materials that we currently use today in castings or machine forms. I think we're limiting ourselves a little bit when we do that. What we're starting to see a general trend in is the development of new materials specifically designed with the very harsh thermal environment during the processing condition. We get a lot of thermal transients during building. Those thermal transients can be very hard on conventional materials, but if we're developing materials specifically in mind of being processed with additive we can actually make better material than we can today with other processes. In the next 10 years you'll start to see customized materials specifically for additive manufacturing.

What are some of the challenges yet to be overcome?

One of the things that I see as a unique challenge in additive manufacturing is as these technologies show promise the additive manufacturing community is growing at a tremendous rate. If you look at some of the reports by Terry Wohlers [of consulting firm **Wohlers Associates**], there's a huge compound annual growth associated with additive manufacturing. In some cases, we can't actually build machines fast enough. There are a lot of companies out there that are machine vendors where if you order a machine today, you may have to wait a year until that machine arrives at your factory, there's that much demand on the industry. ■

Additive Manufacturing Symposium

Event: SAE 2017 Additive Manufacturing Symposium (AMS)
Duration: 2 days including ½ day tour
Location: Knoxville, TN
Dates: March 14-15, 2017

The SAE 2017 Additive Manufacturing Symposium presents:

- Projects and business cases in AM—solutions realized through the implementation of the technology
- Features and benefits and capabilities of 3D industrial-type printers
- Designing for 3D—how and why it is different and the implications
- Development and specifications in AM materials
- Status and activities in AM standards development
- How and why AM will affect your product development, testing,quality assurance and manufacturing

Steel-intensive 2016 Mazda CX-9 sheds mass, debuts novel turbo setup

Other than its aluminum hood, the 2016 CX-9's structure and exterior panels are in various steel alloys. Finally Mazda has arrived at a handsome exterior design language that doesn't resemble origami.

For a mainstream unibody SUV, the 2016 **Mazda** CX-9 pulls off a neat trick—it adds premium content and features while losing weight compared with its predecessor. The design and engineering solutions behind this achievement go beyond expectations for vehicles in this segment and include first use of an all-new, direct-injection turbocharged 4-cylinder gasoline engine with cooled EGR.

For this second-generation CX-9, the changes start with a shift away from the previous CD3 platform shared with former partner Ford. The new seven-passenger CX-9 adopts the same large-Skyactiv platform used by the Mazda3 and Mazda6 sedans, as well as the CX-5 compact crossover. At 199.4 in (5065 mm) long, the new CX-9 is 1.2 in (30 mm) shorter than its predecessor, but its wheelbase has been stretched 2.2 in (55 mm), providing more passenger legroom and easier entry and egress to the rear compartment.

Contributing to the new model's more-distinctive and better-proportioned design are reduced overhangs—2.3 in (59 mm) shorter in front and 1 in (25 mm) shorter in the rear. In addition, the A-pillars are moved 3.9 in (100 mm) rearward.

Shunning aluminum for high-strength steel

The CX-9's other big change is a switch from **Ford**'s 3.7-L V6 to Mazda's first use of a turbocharged version of its Skyactiv 2.5-L 4-cylinder—the sole powertrain offering for CX-9 and rare among three-row crossovers typically fitted with V6s. But according to Mazda vehicle development engineer Dave Coleman, both platform and powertrain changes bring significant weight reductions—198 lb (90 kg) total in the front-drive version and 287 lb (130 kg) in AWD models. Nearly half of that reduction comes from the powertrain switch.

"We improved the strength-to-weight ratio without resorting to materials other than high-strength steel," Coleman told Automotive Engineering. While the car's hood is aluminum, the development team "shied away from more extensive use of aluminum because of its high cost in Japan," he explained.

The weight savings in turn allowed Mazda to increase use of NVH dampening material—53 lb (24 kg) in the CX-9, compared to 5 lb (2.23 kg) in the CX-5. Combined with the use of acoustic glass (window thickness is increased to 4.8 mm/1.9 in), the changes reduce interior noise levels by a claimed 12%.

Equally notable is the powertrain transformation. Shifting to a 4-cylinder-only strategy is potentially risky in a segment where buyers are conditioned to expect a V6, but Mazda's research found that "in real-world conditions consumers are less concerned with 0-60 mph times than they are with drivability at lower engine speeds," Coleman noted.

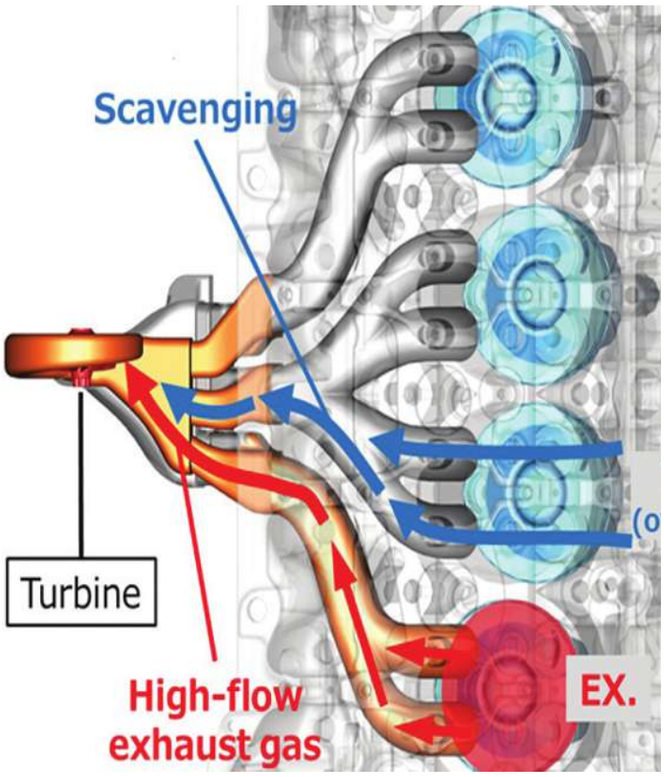
High compression and cooled EGR

This data drove development and tuning of the turbocharged 2.5-L. Addressing the traditional drawback of turbo lag, Mazda engineers developed a new "dynamic pressure" turbocharger layout. This design locates the turbo just one inch from the engine block, connected with a novel 4-into-3 exhaust manifold that pairs the output of cylinders two and three.

At low rpm, the exhaust routes through separate smaller ports to accelerate the gas pressure and more quickly bring the turbocharger to its maximum boost of 1.2 bar (17.4 psi). At higher rpm, valves open to allow exhaust flow through the three larger ports. Pairing the center ports encourages better exhaust gas scavenging, thus raising the knock limit and allowing for a high compression ratio.

Mazda claims the engine's 10.5:1 compression ratio is one of the highest of any production-vehicle turbocharged engine and is enabled in part by use of cooled exhaust-gas recirculation (EGR). Mazda's EGR design cuts exhaust gas temperatures by as much as 212° F (100° C), using EGR rates up to 15%.

The engine produces a claimed 310 lb·ft (420 N·m) at just 2000 rpm. Claimed power is 250 hp at 5000 rpm on 93-octane fuel and 227 hp on 87 octane. EPA fuel economy figures are 22/28 city/highway mpg for the fwd CX-9 and 21/27 mpg for the AWD versions.



Strategically-routed exhaust-gas flow in Mazda's all-new turbocharged DI 2.5-L 4-cylinder gasoline engine.

Bucking the industry trend to 8- or 9-speed automatic transmissions, the CX-9 makes do with a 6-speed unit. According to Coleman, its ratio spread is well-matched to the engine's torque characteristics and avoids the "ratio hunting" issue that afflicts some transmissions with more gears.

Inside, the new CX-9 adopts and expands on the range of infotainment and driver-aid features found in the CX-5. The flagship CUV also offers greater use of upscale materials including, for the first time for Mazda, aluminum, real wood and Napa-quality leather trim. The latter is featured in the new range-topping Signature edition, which sits above the Grand Touring version and starts at $44,015. The base CX-9 Sport model starts at $31,520.

John McCormick

Top-range CX-9 cabin reveals use of premium materials including genuine aluminum. Note central rotary control module in center stack.

Shell Oil shows radical city-car concept

Oil companies typically don't announce concept city cars, but a very non-typical vehicle has altered conventional thought at **Shell**. Its 2016 collaboration with **Gordon Murray Design** and **Geo Technology**, called the Shell Concept Car, is a showcase for bespoke lubricants, engine friction reduction, radical downsizing and super efficiency.

Described by Shell as a "total rethink" of Murray's T.25 city car shown in 2010, the Shell Concept Car has emerged from the Project M (for Mobility) previously revealed (see http://articles.sae.org/14478/) as an ultra-compact and extremely frugal 3-seat, single-canopy access city car.

A salient figure quoted in a statement by Shell is that "independent testing and a rigorous lifecycle study shows that Shell's Concept Car would deliver a 34% reduction in primary energy use over its entire lifecycle when compared to a typical city car available in the U.K."

Regarding the car's efficiency, Shell states that its gasoline consumption has been measured using a range of testing protocols. Sample test results issued so far include a steady state figure of 2.64 L/100 km [89.1 mpg U.S.] at 70 km/h from the use of bespoke lubricants, equivalent to a 5% improvement in fuel efficiency (and consequent improvement in emissions) compared to standard lubricants available in the U.K.

No urban or combined fuel consumption figure has been released but an aspirational Project M target was a combined figure of 2.8 L/100 km.

Access to the Shell Concept Car involves a single canopy.

Interior of the Shell Concept Car follows the configuration of the Gordon Murray Design T.25 and of the Project M.

Just 8-feet long

The 2.5-m-long (8.2-ft) Shell Concept has a potential top speed of 156 km/h (97 mph), higher than the anticipated speed of 130 km/h/81 mph). Currently the design is restricted to 145 km/h (90 mph) and is claimed to reach 100 km/h (62 mph) from standstill in 15.8 s. The engine is a **Mitsubishi** 660cc 3-cylinder, all-aluminum 4-valve unit with variable valve timing. Claimed power output and peak torque are 33 kW (44 hp) and 64 N·m (47 lb·ft), respectively. The engine drives through a 5-speed semi-automatic sequential gearbox.

The Concept Car weighs 550 kg (1213 lb) and makes extensive use of recycled carbon fiber (wherever *that* comes from).

Shell Global Lubricants' Vice President, Mark Gainsborough, noted the project's value in energy saving R&D: "This is a significant automobile engineering milestone. Insights gained from this project could be transformed in terms of how we address energy use in the road transport sector," while noting "the powerful role that lubricants can potentially play in helping achieve CO_2 reduction targets."

Stuart Birch

Embraer's first E190-E2 jet takes off early

Embraer's E190-E2 will share cockpit with the aircraft it will be replacing, but be equipped with new wings and Pratt & Whitney geared turbofan engines.

Embraer's E-Jets E2 program took an important step forward with the recent completion of the maiden flight of the E190-E2 from its facility in São José dos Campos. The flight occurred just three months after the E190-E2 made its public début at a rollout ceremony at the factory in late February. The flight was originally scheduled not to take place until the second half of this year, though program development of the E2 was expedited by the extensive use of digital modeling simulations and ground and static tests that employed rigs and an iron bird.

The inaugural flight marked the beginning of the certification campaign for the E190-E2, the first of three new second-generation E-Jet models. The E190-E2 is scheduled to enter commercial service in 2018.

The flight entailed the evaluation of aircraft handling and performance characteristics with the crew analyzing a significant number of flight parameters, including speed, altitude, and landing gear retraction. The crew took the aircraft to Mach 0.82 and climbed to 41,000 ft.

The aircraft that flew is the first of four prototypes that will be used in the E190-E2 certification program. Two additional aircraft will be assigned for the E195-E2 certification process that will lead to entry into service in 2019. Three more aircraft will be used to certify the E175-E2, which is scheduled to enter service in 2020.

E-Jets E2s are based on the proven platform of the current-generation E190, but with more advanced technologies applied such as new aerodynamically advanced high-aspect ratio wings, improved systems and avionics, fourth-generation full fly-by-wire flight controls, and **Pratt & Whitney**'s PurePower GTF engines (PW1700G on the E175-E2, PW1900G on the E190-E2 and E195-E2). Embraer says those technologies combine to generate double-digit reductions in fuel consumption, emissions, noise, and maintenance costs, as well greater productivity though less scheduled maintenance downtime. What they will share is a common cockpit, which will allow for a smooth transition to the new aircraft. E-Jets E2s are expected to achieve similar costs per seat as larger, re-engined narrow-body aircraft but with lower costs per trip.

Embraer initially rolled out its new E190-E2 in February, with its first flight occurring in late May.

The E190-E2 has the same number of seats as the E190 and can be configured with 97 seats in dual-class or 106 seats in a single-class layout. However, it has 400 nmi more range than the E190 and gives operators the ability to fly the aircraft up to 2800 nmi.

Since the E-Jets E2s were launched in June 2013, the program has logged 640 commitments from airlines and leasing companies: 267 are firm orders and 373 are options and purchase rights. The E-Jets family of aircraft is the leader in the up-to-130-seat aircraft category with more than 50% worldwide market share. Embraer E-Jets are currently in service with some 70 customers from 50 countries.

Jean L. Broge

Western Star debuts Extreme Duty Offroad package, new 'transformer' chassis

The 6900XD Offroad MBT-40, dubbed the Multi-Body Transformer for its ability to quickly change from one fully functional in-cab-controlled body application to another, is the first XD Offroad series offering from Western Star and reportedly a new concept for off-road equipment markets.

The MBT-40 features multiple hydraulic, air and electrical connections that allow it to connect to and power a variety of body needs, from flow-controlled hydraulic motors and pumps to heavy high-flow tip cylinders.

Western Star is known for its tough vocational trucks and now offers an off-road product that competes with the articulated and rigid frame markets. The truck maker recently announced its new Extreme Duty (XD) Offroad package and the launch of the MBT-40 Transformer chassis.

Available on both the 4900 and 6900 models, the Western Star XD Offroad package is engineered specifically for extremely rugged environments. The 6900XD Offroad MBT-40, dubbed the Multi-Body Transformer for its ability to quickly change from one fully functional in-cab-controlled body application to another, is the first XD Offroad series offering from Western Star and reportedly a new concept for off-road equipment markets.

Vehicles spec'd with the XD Offroad package provide customers with a low cost per ton product for offroad applications, the company claims. Western Star plans to expand the XD Offroad package to other models in the future.

"The MBT-40 package is a game changer in construction applications for its ability to be multiple pieces of equipment in one chassis," said John Tomlinson, XD and vocational sales manager, Western Star. "The development of this platform was all about finding better economic ways of filling needs for our customers. Off-road chassis equipment can be expensive to buy and maintain and new emissions levels are making the investment even more costly."

Using a **Palfinger** G68 hooklift, which has a lifting capacity of 68,000 lb (30,850 kg) and a new transformer package, the MBT-40 gives customers greater utilization of their chassis. It can take the place of multiple pieces of dedicated off-road equipment on a job site that sit for long periods of time when they're not needed. It is applicable for extremely complex and heavy capacity bodies.

The unit is equipped with a generic in-cab control system and a self-adapting hydraulic system that also allows the operators to quickly and easily swap the controls of multiple body applications. The MBT-40 features multiple hydraulic air and electrical connections that allow it to connect and power a variety of body needs from flow-controlled hydraulic motors and pumps to heavy high-flow tip cylinders.

Bodies can be swapped two or three times a day to maximize

The MBT-40 can take the place of multiple pieces of dedicated off-road equipment on a job site that sit for long periods of time when they're not needed. It is applicable for extremely complex and heavy-capacity bodies.

Carco Industries worked with Western Star to test the open platform concept on its equipment.

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Using a Palfinger G68 hooklift, which has a lifting capacity of 68,000 lb (30,850 kg) and a new transformer package, the MBT-40 offers customers greater utilization of their chassis.

output efficiency.

"By maximizing the operation time, customers can have the equipment they need always for when it is required," Tomlinson added. Mining, quarry and off-road construction industries can benefit from this new product, he said.

Carco Industries worked with Western Star to test the open-platform concept on its equipment and the truck maker is working to expand the MBT's capabilities. The unit can be adapted to suit other body companies.

"Carco Industries is very experienced in mining and off-road fuel and service products along with carrying the Palfinger crane lines," said Charlie Schimmels, sales manager, Carco Industries. "This combination of experience and product along with the rugged design and carrying capacity of the XD40 Offroad chassis offered by Western Star makes the MBT-40 package a very unique product. With commodity prices down and budget cuts becoming common place, we need to think smarter about how we do business and the MBT-40 does that."

The 6900XD is available in both 6x4 and 6x6 configurations.

Ryan Gehm

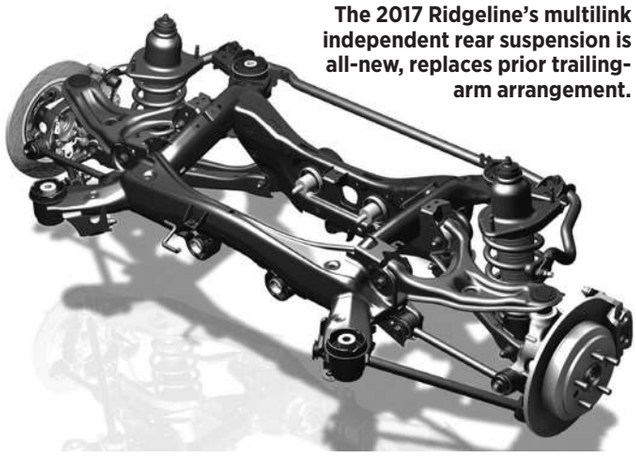
Second time a charm for Honda's unibody Ridgeline pickup?

The 2017 Ridgeline midsize pickup truck is longer overall and has a larger cargo bed, but is somewhat lighter, thanks largely to a body of 60% high-strength steel.

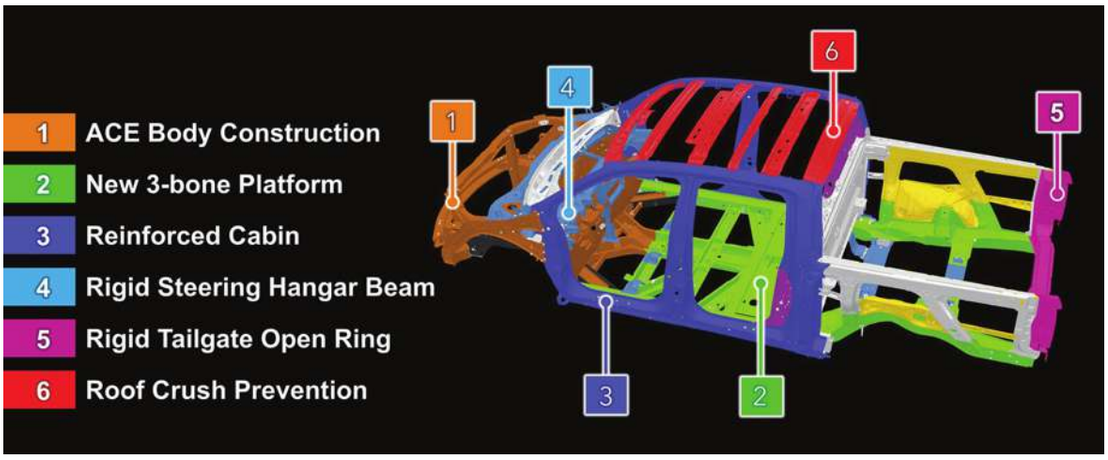
Although its best-ever sales year was barely more than 50,000 units and many critics questioned the buying public's desire for a midsize pickup based on a unibody structure instead of the tried-and-true body-on-chassis layout, **Honda** remained faithful to the concept it introduced with the first-generation Ridgeline pickup, producing it for ten years from 2005-2014.

Even through the recession and auto-industry downturn, Honda insisted it was keen to develop a second-generation Ridgeline, to continue to press the idea that if many in pick-up-crazed America took an honest look at what they want from a pickup—and equally important, how they actually use a pickup—a unibody-based design would be the most satisfying choice.

So here's Honda with the 2017 Ridgeline and it seems the conditions are more favorable than ever for the company to prove its point: the U.S. market remains in a highly absorptive mood for pickups, new midsize models such as **General Motors**' **Chevrolet** Colorado and **GMC** Canyon have reinvigorated demand in a segment recently decreed as stagnant—and not of inconsequential importance, the 2017 Ridgeline also happens to be a pretty convincing effort.



The 2017 Ridgeline's multilink independent rear suspension is all-new, replaces prior trailing-arm arrangement.



Optimized body structure is nothing new, but Honda said it helps the Ridgeline attain an expected 5-star safety rating, something body-on-frame rivals have yet to achieve.

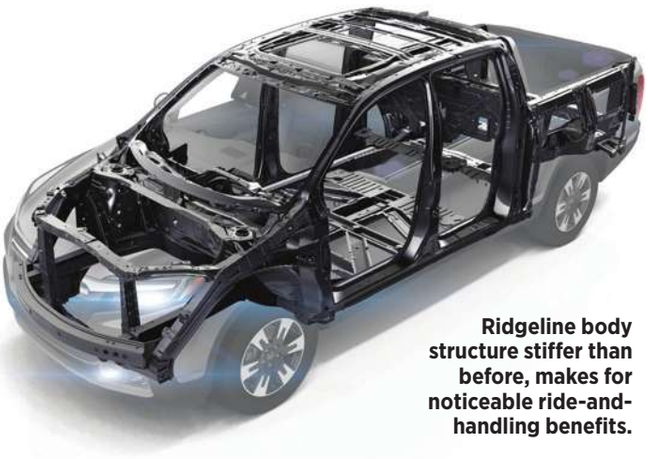
Non-issue styling

The big news for the 2017 Ridgeline is that it no longer looks wacky. Gone are the previous model's thick side buttresses aft of the cab that blended into the bed, giving the truck a distinct "hybrid" appearance—a look Honda believes was another "avoidance" factor for comparison shoppers that already needed convinced why they shouldn't just buy a conventional pickup from the established players.

So although the new Ridgeline isn't the same as its body-on-frame competitors, it's been deliberately styled to look the same, particularly in that crucial area where the cab meets the cargo bed. Apart from not scaring off customers, the straightforward look has another advantage: the Ridgeline's bodyside no longer needs to be a one-piece stamping, a part that caused assembly-plant fits. The new Ridgeline now is the only Honda made in North America with bolt-on rear fenders. And one further advantage: if a rear fender is damaged, the new design makes for easier and less-costly repair.

Pilot-related structure

The 2017 Ridgeline utilizes a well-modified variation of Honda's Global Light Truck architecture, which also underpins the Pilot and **Acura** MDX crossovers; for example, 50% of the Ridgeline's suspension is reengineered compared with the Pilot, while the big takeaway in size difference is overall length and wheelbase: the new Ridgeline, at 210 in (5335 mm) overall, is 3.1 in (79 mm) longer and wheelbase grows at subsequent 3 in to 125.2 in (3180 mm). Bed length is a handy 64 in, almost 4 in longer than before and a couple inches longer than the Colorado and **Toyota** Tacoma "short" beds. The former Ridgeline's innovative in-bed cargo trunk is here again, as is the useful swinging or folding tailgate. Honda's proud of a new sound system that reverberates the bed walls for a big-time tailgating experience; to us it seems superfluous but only comes on the two top-trim models, at least.



Ridgeline body structure stiffer than before, makes for noticeable ride-and-handling benefits.

Used to be the talk about unibody pickups often centered on a presumed weight-saving potential, but that's not so much the case here: the base AWD configuration weighs about 4431 lb (2010 kg), said Honda—that's 73 lb (33 kg) lighter than before, but not much lighter than a comparable Toyota Tacoma (4480 lb) and a touch heavier than the 4390-lb Chevy Colorado. No, the distinct payoff from the Ridgeline's structure is refinement and on-pavement dynamics; it's smoother and quieter inside, steering is more direct and there's a noticeable lack of body movement and shudder. Honda said the new-generation Ridgeline is 28% more torsionally stiff—and the previous Ridgeline already had class-leading bending performance.

The unibody structure also enables a much larger storage area under the rear seats and class-leading cargo volume with the rear seats folded, said Kerry McClure, chief engineer and development leader who also was a member of the original Ridgeline's engineering team. He also said Honda expects a 5-star safety rating for the new Ridgeline, a score no body-on-frame midsize pickup has yet achieved. But it's not as if there isn't lightweighting going on, Honda body and manufacturing engineers told *Automotive Engineering*. They said the new model is larger and has more content, yet weight nonetheless was reduced. One factor, they said, was markedly increased use of high-strength steels, where HSS accounts for about 60% of the 2017 Ridgeline's body in white, compared with just 5% before.

The MacPherson strut front suspension and multilink rear suspension are up-fitted from the Pilot's design, with several crucial pieces, particularly knuckles and subframe mounts, suitably beefed for pickup duty. The layout makes for immensely satisfying on-road behavior and doesn't seem an impediment for hauling, towing and medium-rough off-roading.

Two-spec powertrain

All 2017 Ridgelines are powered by a new version of Honda's 3.5-L DOHC V6 that develops 280 hp and 262 lb·ft (355 N·m) of torque, increases of 30 hp and 15 lb·ft compared with the previous 3.5-L V6 and right on the 278 Toyota's Tacoma gets from its 3.5-L V6, while the Colorado gets 305 hp from its 3.6-L engine.

The Ridgeline bucks the broad industry's transmission trend, though, in sticking with just six forward speeds for its planetary automatic. Engineers said they're satisfied with performance and fuel-efficiency with the 6-speed unit and it appears for now that margins and caution have kept any automakers from making the leap to more ratios for midsize pickups. We suspect Honda's forthcoming 10-speed automatic could be a future upgrade, particularly if the much-discussed mid-term review of federal fuel-efficiency regulations doesn't yield any rollbacks.

Meantime, though, there's other driveline interest. The 2017 Ridgeline offers a 2WD variant for the first time (in this case, that means front-wheel drive). The company said it can't ignore the interest in 2WD from fair-weather markets such as California, Texas and Florida and the 2WD option presents the opportunity to hit showrooms with a base price under $30,000. All-wheel-drive models are fitted with the i-VTM4 differential that incorporates torque vectoring. It's 22 lb (10 kg) lighter than before and is 40% faster in sending torque to the rear axle, while either rear wheel can be over-speeded by as much as 2.7% to influence cornering.

The 3.5-L V6 is the Ridgeline's sole engine, revised with more hp and torque and with variable-cylinder management to operate in fuel-saving 3-cylinder mode.

The fold-or-swing tailgate that became a Ridgeline hallmark returns for the second-generation truck. Opens to a bed with class-leading payload capacity.

Ridgeline interior is the antithesis of "trucky," raft of available electronic safety features is uncommon for the segment.

The i-VTM4 also collaborates with the Ridgeline's new Intelligent Traction Management system that permits toggling between normal, snow, mud and sand settings for AWD models and normal and snow for 2WD. A button gets the driver between the settings; we think a console- or dash-placed rotary knob would be more in keeping with the Ridgeline's mission.

Yeah, but is it a 'real truck?'

The 2017 Ridgeline seems like enough truck for most needs. The AWD models' 5000-lb (2268-kg) standard tow rating, as derived from **SAE** standard J2807, is enough for 95% of towing that midsize-pickup buyers require, according to a third-party survey conducted for Honda, while the Colorado and Tacoma are rated to tow up to 7000 lb with special upgrades.

With 8 in (203 mm) of ground clearance, the Ridgeline is near the Colorado's 8.2 in, but a little afield of the Tacoma's 9.4-in ground clearance. Honda didn't supply off-road approach and departure figures, but given the comparatively minor differences in the major comparison points, the Ridgeline appears capable of standing toe-to-toe with its body-on-frame competition in most measures—particularly, as Honda's always noted, when real-world use of midsize pickups is the baseline consideration.

The 2017 Ridgeline "is not an exercise in compromise," summarizes Jeff Conrad, senior vice president and general manager of the Honda Division. "It's an all-new pickup for a new generation."

Honda tried once and it didn't quite fit. But the Ridgeline developers' realistic appraisal of how most pickups actually are used may find a more receptive audience this time around. High refinement and a "plenty capable" approach to utility could make unibody pickups a concept whose time has come. Anybody remember how the Toyota RAV4 and Honda's CR-V changed how the world looked at SUVs?

Bill Visnic

COMPANIES MENTIONED

AD INDEX

Q&A

Kazuaki Shingo: Showing the world Toyota's capability. (Photo by Lindsay Brooke)

Pride in engineering the world's most popular electrified vehicle

Kazuaki Shingo's background is in mechanical engineering and internal combustion engines—making him a perfect candidate to develop the world's most popular electrified car! The Assistant Chief Engineer of the 2016 (fourth generation) Prius chuckles when he tells you that, recalling his seven years spent in control-systems design after joining **Toyota** as a university graduate in 1996. Shingo-san then got his wish to enter product planning, with subsequent moves back into development of the second-generation Prius hatchback, and the Auris and Prius V programs. He spoke with *Automotive Engineering* through an interpreter at the 2016 Prius North American media launch.

Were you excited when the fourth-generation Prius was chosen to be the first vehicle developed on TNGA—Toyota's new global architecture?
Yes! A lot of new Toyota technologies are incorporated into the latest Prius. The new platform raised the bar way up high for us who were developing the car. In fact, in the beginning I was working on both the new platform and the car. We felt this was a great chance for us to really capitalize on the new structure to make the car better. And that's what happened.

What challenges did moving to the all-new TNGA present to your development team, and what benefits did TNGA provide?
There were many challenges. For most of the components we started from scratch. Then it was difficult for team members to integrate the many, many requests for the platform from other departments and projects! But the new global platform created a 'volume effect' that make the vehicle prices more affordable. And it gives us more freedom to engineer different variants.

Also, at the time we were creating the new platform, we faced a number of challenges that came one after the other: first the 'Lehman Bros. shock' then we had a big earthquake in Japan and also Toyota had some quality-related problems. Not only that, the global market was shifting from the developed countries to the developing countries. I felt the crisis was so significant that our company might not be able to keep afloat. So the company decided to 'go back to basics' and create something affordable and with high quality. It was a company-wide decision to focus our efforts on that idea. In order to do that, intra-divisional walls were eliminated. Everybody got together and collaborated. We knew we had something that Japan is very proud of: the ability to manufacture products with very high quality. That spirit enabled us to move forward through the challenges.

In developing the new Prius, what were the three main customer desires for the new model?
Prius is Toyota's 'hybrid DNA' so we wanted to maintain the world's best fuel economy. That was number one. Second, while the previous model's fuel economy is very good, we also knew that road noise, ride comfort and handling weren't as good. On a long trip the fatigue level was not so good, and the handling needed improvement. So we wanted to rectify those areas. We wanted the new Prius to be a fun car to drive. And third was the interior aspects—some voices we heard said the old interior was too 'plasticky.' So based on those voices we revisited the interior and spent a lot of time on the seat design.

Was there an aim to reduce the weight of the new Prius compared with the previous one? You did say the lithium-ion batteries contribute to less weight.
Mass reduction was one of the greatest challenges we had in this development because the fuel economy is very important to us. Making sure the vehicle stays light was one of our most important aims. In addition to that, U.S. collision safety and fuel economy regulations were becoming very stringent; we had to cope with higher collision speeds. Also, to improve ride and handling we decided to install a double-wishbone rear suspension which caused us to raise body rigidity to a higher level. These and other things resulted in an increase in vehicle mass so to compensate we used more aluminum components and high-tensile steel. In the end we achieved a weight level comparable to the older Prius.

The white body is steel, with an aluminum hood and liftgate. Was there ever a plan to make Prius aluminum-intensive?
Yes, we gave consideration to use of aluminum in more areas. Because this vehicle was going to be produced using the TNGA, that meant it had to be designed for production anywhere in the world. It was a business decision that we had to protect. Also, obtaining aluminum for processing is easy in the U.S. and Japan, but not so easy in developing countries.

What is your greatest achievement on the fourth-gen Prius?
I'm most proud of developing the new hybrid system and also its new platform built from scratch. It's one way to show the world Toyota's capability.

Lindsay Brooke

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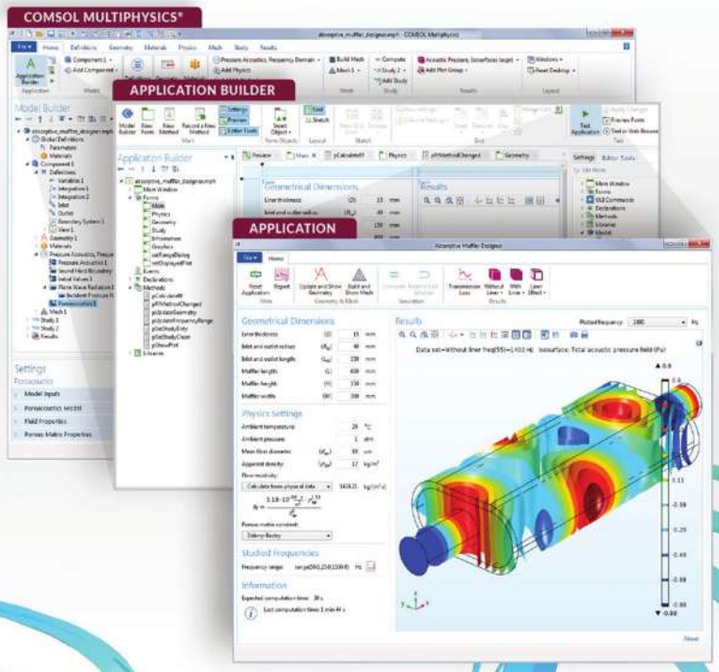

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