MOBILITY ENGINEERING™

AUTOMOTIVE, AEROSPACE, OFF-HIGHWAY

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India's new-age Jeep

Tata to build Safari Storme for Indian Armed Forces

Alt-fuels for aircraft

What lies ahead

IC's next big thing

Achates Power's opposed-piston engine heads for production

Volume 4, Issue 2

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Thanks to a recently-signed contract, Tata Motors will supply nearly 3200 units of the Safari Storme 4×4 to the Indian Armed Forces under a new category of vehicles known as General Service 800.

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Hot time for ‘cold’ combustion

At a time when the world seems fascinated with the prospect for electric vehicles, evidence is mounting that a quick or comprehensive transition away from internal combustion isn’t going to be how this all transpires.

There’s no doubt the vision of zero tailpipe emissions—as well as a release from the other environmental and geopolitical baggage of fossil fuels—is attractive. But the proceedings at the **SAE**’s latest edition of its annual High-Efficiency IC Engines Symposium in Detroit convinced me, once and for all, that electric vehicles are going to be role players for most of our foreseeable lifetimes.

Internal-combustion engines and the liquid fuels to power them soldier on as a recipe that’s hard to beat—at least economically.

Most speakers at the April symposium, which preceded SAE’s annual WCX17 (formerly known as World Congress) conference, illustrated in some fashion that the energy density of petroleum-based fuels—in conjunction with engineers’ increasingly sophisticated innovations for engines that eke out more work from every joule in those fuels—essentially is efficiency at its best.

First, the fuel. Wayne Eckerle, vice president—Corporate Research and Technology at heavy-duty engine specialist **Cummins**, flatly said, “liquid fuels will dominate transportation for years to come.” Thomas McCarthy, chief engineer for Powertrain Research & Advanced Engineering at **Ford**, showed data to indicate that at least from a CO_2-reduction standpoint, an EV delivers little well-to-wheels gain over a liquid-fueled IC vehicle. Both McCarthy and Dave Brooks, director for **General Motors** Global Propulsion Systems R&D, advocated for the comparatively low-cost efficiency gains to be derived from higher-octane, higher-reactivity fuels in new IC engines designed to exploit those fuels.

Hand-in-hand with this reality check regarding liquid fuels was recurring discussion at the symposium— highlighted by a revelatory presentation by Mark Sellnau, engineering manager, **Delphi** Advanced Powertrain, regarding his company’s latest-generation gasoline direct injection compression-ignition (GDCI) engine—regarding so-called low-temperature combustion, which in effect combines the attributes of gasoline and diesel engines.

Delphi’s GDCI uses a 16:1 compression ratio to sparklessly ignite partially premixed gasoline and air across the entire engine operating range. This differs from homogenous-charge compression-ignition (HCCI) low-temperature combustion engine designs, which use spark ignition under certain conditions. Delphi’s third-generation GDCI four-cylinder engine is projected to achieve 42% brake thermal efficiency and surpass the efficiency of a typical 2.0L diesel engine by about 11%, Sellnau said.

Delphi began testing the third-generation GDCI engine early this year and although it’s given no timeline for potential production use—Sellnau was clear that challenges remain, chief among them exhaust aftertreatment requirements—he promised the engine will operate with gasoline at currently-available octane. “We really need to get to market with commercial gasoline,” he said.

The promise of low-temperature combustion engine design seems comparable to what the industry has derived from advancing to direct fuel injection from conventional port fuel injection. Michael Olechiw, director of the U.S. **Environmental Protection Agency**’s Light-Duty Vehicle and Small-Engine Center, reminded symposium attendees that the “mainstreaming” of direct-injection, which now is found on about 50% of all light-vehicle engines sold in the U.S., largely has been responsible for adding a couple of percentage points of peak thermal efficiency at modest incremental cost.

I juxtapose this with the news, just as this issue went to press, that India’s Power Minister, Piyush Goyal, suggests only EVs should be sold in India by 2030. It’s certainly a provocative suggestion to address India’s worsening air-quality and it was met mostly with mix of criticism and ridicule. Despite that, it might be the right answer for India; but I wonder if Mr. Goyal would have the same perception of burning fossil fuel if he was aware of the IC engine advances that appear to be just around the corner?

Bill Visnic, Editorial Director

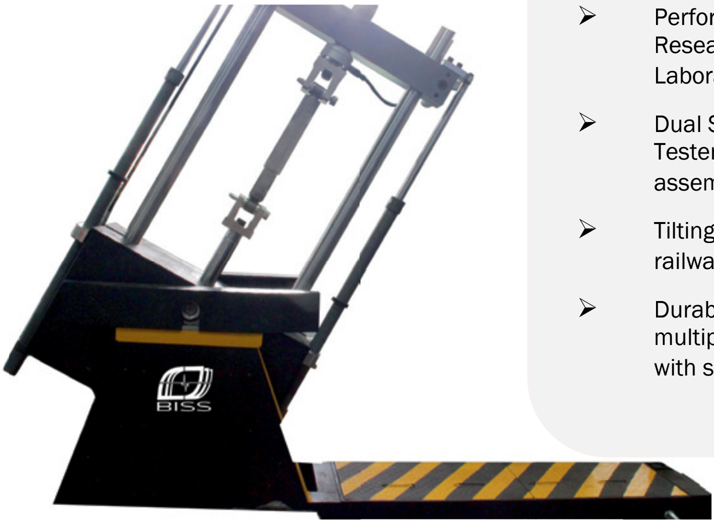
25 Years of Innovation in Mechanical Testing

India's leader in Shock Absorber Testing

BISS a subsidiary of ITW, USA is India's largest manufacturer of high performance servo-hydraulic test equipment with a strong presence in the auto industry. BISS equipment across the country serve as virtual guarantors of shock absorbers produced by most reputed companies, with more than a million parts tested for quality each month. BISS now offers a wide range of solutions for performance and endurance testing. This includes single and multi-axis testers of dampers and other chassis components, right up to four-poster road simulation and 3-axis 6DOF shake tables.

BISS also operates the largest privately owned ISO17025/Nadcap accredited test laboratory in India performing 24/7 testing for a variety of multinationals.

Dual Station Production Line Shock Absorber Tester



Tilting Shock Absorber Tester

Shocks Testing Products:

- Performance Testers for Research and Development Laboratories
- Dual Station Production Testers for high productivity assembly line testing
- Tilting Shocks Testers for railway applications
- Durability Testers to test multiple shock absorbers with side load applications

Material Testing Solutions

SAEINDIA News

Erode Division inauguration

Mr. S. Sriraman, Chairman of SAEISS, presents the memento to Mr. Venkatachalam, Correspondent of Kongu Engineering College.

Dr. P. Navaneetha Krishnan, Chairman of the **SAEISS** Erode Division, delivered the welcome address and Mr. Venkatachalam, Correspondent at **Kongu Engineering College** (KEC), in January welcomed members of SAEISS for the inaugural function of Erode Division. Dr. Kuppusamy, Principal at KEC, used the occasion to explain the activities of the college.

Dr. P. Navaneetha Krishnan invited the dignitaries, Mr. S. Sriraman, Chairman of SAEISS, Dr. E. Rajasekar, Secretary of SAEISS, KEC's Mr. Venkatachalam, Dr. Kuppusamy, Principal at KEC and Dr. Eswaramoorthy, Secretary of the Erode Division, to take the dais. Dr. P. Navaneetha Krishnan invited all the members on the dias to light the kuthuvilakku.

Mr. S. Sriraman explained the SAEISS organization and Dr. E. Rajasekar provided further details about the activities of SAEISS and welcomed the SAEISS chairman to present the memento to the hosting college. Mr. S. Sriraman presented the hosting college memento to Mr. Venkatachalam and Mr. Srirman also thanked KEC for hosting the important event.

Dr. E. Rajasekar introduced the Erode Division MC members to the participants. Dr. R. Rajendran delivered the inaugural address for the KRT Club and Mr. S. Sriraman inaugurated the KRT club at KEC. Mr. T. Kasiraja, Treasurer of SAEISS, expressed thanks to the hosting college and participants of the Erode Division inauguration, while a vote of appreciation was given by Dr. P. Somasundaram, HOD of the Automotive Engineering Department of KEC.

SAEISS Erode Division MC Members.

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SAEINDIA News

Symposium on International Automotive Technology 2017 in Pune

The Symposium on International Automotive Technology (SIAT) 2017, organized in January by **ARAI** in Association with **SAEINDIA**, **NATRiP** and **SAE International**, was a grand success. The theme of SIAT 2017, "Smart, Safe and Sustainable Mobility," was developed to align with the latest trends and future challenges being faced by the automotive community.

The SIAT Expo 2017 included around 180 exhibit booths showcasing products and technologies by global automotive and allied manufacturers and suppliers in areas such as BS VI, vehicle safety and crash technology, electric mobility, vehicle telematics, advanced T&M equipment, NVH, and simulation and modelling. The SIAT Expo also served as a memorable grand finale for ARAI's yearlong Golden Jubilee celebrations.

SIAT 2017 and SIAT Expo 2017 were graciously inaugurated by Shri Sanjay Mitra, Secretary, Ministry of Road Transport and Highways and Shipping for the government of India. The function also was honored by the presence of Dr. R. K. Malhotra, President of SAE India, Shri Sanjay Bandopadhyaya, CEO, NATRiP, Shri T. Mookiah, Associate Director (R&D), **VSSC** and Mr. Murli Iyer, Executive Advisor – Global, SAE International.

The function also included the release of SIAT 2017 proceedings, distribution of the India Emission Regulations booklet, ARAI Golden Jubilee awards and prize distribution for the Road Safety Awareness Short Filmmaking Contest. Other activities included the release of the book "Road Safety—A Collection of Cartoons," by Mr. Mangesh Tendulkar and the unveiling of a demonstration electric vehicle using an indigenously-made lithium-ion battery.

The SIAT inaugural address by Dr. R. K. Malhotra.

The SIAT event includes for plenary sessions on smart, safe, sustainable and future mobility. A Student Poster Presentation Competition was organized for SIAT to motivate young thinkers; a total of ten posters addressing the four plenary-session mobility topics were displayed.

The valedictory function concluded with Chief Guest Shri. Anant Geete, Honorable Minister for Heavy Industries and Public Enterprises for the government of India and Guest of Honor Mrs. Eva Molnar, Director of the Sustainable Transport Division, **UNECE**, presenting the awards for the best papers, best Expo booths, release of the ARAI Golden Jubilee Souvenir, the Young Engineer 2016 award and the launch of Technology for Autonomous Driving. The event was a true technical feast for the approximately 1,400 delegates from 21 countries who participated.

The next SIAT occurs in January 2019.

Dr. Pawan Goenka addresses the Smart Mobility plenary session.

Dignitaries at the Symposium's valedictory function.

Aero Design Challenge workshops in Chennai

The **SAEINDIA** Southern Section in January, February and March conducted its Aero Design Challenge workshops at three locations—**GRT Institute of Engineering Technology**, **Valliammai Engineering College** in Kattankulathur and **JEPPIAAR SRR Engineering College**, OMR in Chennai. A total of 300 student members of SAEINDIA from various engineering institutions across India participated in the workshops.

At each location, the inauguration of the event was conducted by Dr. S. Senthilkumar, Champion-Aero Design Challenge (ADC) and professor at **Veltech University** in Chennai. He also welcomed the dignitaries and participants for the Aero Design Challenge workshops and also gave a brief outline about the goals of the workshop. Dr. Senthilkumar noted that 94 teams across India registered to participate in the 2017 version of the Aero Design Challenge and he congratulated the students for their interest in continuous learning through **SAE** events.

Mr. S. Shanmugam, Managing Director, **DDIPL**, spoke about the evolution of SAE and SAEINDIA and highlighted the impact of the Aero Design Challenge. He encouraged the students to take part in the continuous learning process through various SAE student activities and thanked the hosting colleges by presenting each college with a memento. **SAEISS**'s Mr. Karthikeyan explained to the students the basics of aircraft design, including aerodynamic forces, main components, control surfaces and their functionality and airfoil and wing design procedures. He also detailed design tools, and stability and performance parameters, propulsion system and avionics systems and control surfaces for Unmanned Aerial Vehicles (UAVs).

Aero Design Challenge students fly the aircraft they designed.

Using supplied kits, the students started work on design and fabrication of aero model as per the trainers' instructions. All the UAV models underwent a pre-check carried out by the trainers and flyers prior to the flight test in order to achieve proper stability. The flyers then tested each team's flight model, with the dynamic performance of the models dependent on the team's accuracy in building the model. The process taught understanding and appreciation for the importance of accuracy and role of each control surface for a successful flight.

Dr. S. Senthil Kumar, Dr. R. Krishnakumar and other ADC Members answered the students' queries after the flight testing. The function ended with a vote of thanks by Dr. S. Senthil Kumar.

Aero Design Challenge teams with their aircraft.

SAEINDIA News

SAEINDIA National Student Convention in Perundurai

The 11th annual **SAEINDIA** National Student Convention was held at **Kongu Engineering College** (KEC) in Perundurai in February, 2017. Each year, the SAEINDIA collegiate chapters use the convention as an opportunity to discuss, display and celebrate their successes of the past year. The 2017 convention saw active participation from than 1,100 students from 81 colleges.

The Inaugural function started with the welcome address by Dr. S. Kuppuswami, Principal at KEC, followed by the Presidential address from Mr. S. Sriraman, Chairman of **SAEISS**. A special address was delivered by Thiru. A. Venkatachalam, Correspondent at KEC. Both Mr. S. Sriraman and Thiru A. Venkatachalam introduced Mr. Aravind Raman, GM of **Bosch**, as the Chief Guest for the 2016-17 Student Convention.

The convention's first-day highlight was the battle among students representing the six divisions of SAEISS who were winners of Tier 2 regional competitions that included an automotive quiz, aero modeling, modeling and animation, CNC turning and milling, CAD/CAM and mobile robotics.

On the second day, the participants competed in 17 events that included mobile-app development, reverse engineering, the Internet of Things, biomimicry, ethical hacking and onboard diagnostics.

On the sidelines, SAEISS also conducted a Technology Theatre for the students. There were three sessions: Digital Manufacturing, handled by Mr. Rohit Mallya, Head, Technical Marketing, **Ranal Software Technologies**; that was followed by a session titled "Vehicle Design—Past, Present and Future," by Mr. C. Pradeep, Principal Engineer, **Mahindra & Mahindra** and a final session on lithium-ion batteries by Mr. Kannan, Senior Lead Engineer, Mahindra & Mahindra.

There also were club presentations showcasing the achievements, strengths and unique activities of various SAE collegiate chapters. A Club Display competition ran parallel with the technology theatre at each venue, with various working mechanical models, presentations and charts.

During the valedictory function, Chief Guest Mr. R. Sridhar, Sr. VP, Mahindra & Mahindra, enlightened the students with his lecture on "The Winning Ways." Mr. S. Sriraman and Thiru. A. Venkatachalam presented the Chief Guest with the memento and also thanked him for his eye-opening lecture. This was followed by the distribution of prizes and mementos and Mr. C. Nandagopalan, SAEISS Student Convention Champion, delivered the vote of thanks.

Awarding the winner of the event.

Dignitaries of the Student Convention.

Tenth annual Baja SAEINDIA in Pithampur

A Baja SAEINDIA participant in action.

The endurance-testing portion of the Baja competition.

Team Baja SAEINDIA 2017.

The tenth annual edition of Baja **SAEINDIA** took place this past February at Pithampur, Indore. The national-level competition for engineering undergraduates, which began in 2007, brought all-terrain vehicle (ATV) entries from more than 175 engineering colleges competing for the title of the overall champion and monetary awards. The event was held on the expansive premises of the **National Automotive Testing and Research & Development Infrastructure Project** (NATRiP) and attracted participation from 35 eBaja teams and 150 teams for the mBaja.

As usual, the Baja event was divided into various stages, starting with the technical evaluation of the vehicles, followed by static events, dynamic events—and finally, the most-awaited endurance race. The event's first day incorporated the registration process for the teams and proceeded toward the all-important technical evaluation process. As well as the overall inspection of the vehicle by the specially trained judges from the automotive industry, the day also included testing for the vehicles' engines and braking systems.

Continuing into the second day, the teams that cleared their technical evaluations become eligible for the dynamic events at the NATRiP proving grounds. In conjunction with this process were static evaluations for design, sales, cost metrics and others, all of which had changes in their conduct and methodologies for 2017.

The dynamic events were opened to the teams on the first day and went on for the entire third day, too. In addition to the existing range of the dynamic events was a new test: the sled pull. Parallel to the course, the eBAJA teams also had their respective technical evaluations and dynamic events at the track. The endurance race also was successful on the penultimate day of the event.

The final showdown of the endurance race took place on SAEINDIA Baja 2017's last day. Team Avishkar from **NIT Jalandhar**, which also built the lightest vehicle at the competition, started at the coveted pole position during the 4-hour extravaganza. The race concluded with Team Nemesis from the **College of Engineering Pune** and Team Kraftwagen from **Sinhgad College of Engineering Pune** grabbing the title of the 'Overall Winners' for mBaja and eBaja respectively.

The valedictory ceremony brought an official close to the event, with various prizes being distributed in both the mBaja and eBaja categories. The ceremony also included the launch of a Baja coffee-table book commemorating ten years of the grueling Baja competition in India.

SAEINDIA News

Manovegam Virtuals 2017 in Tumkuru

The **SAEINDIA** Bengaluru section conducts various competitions and activities for students to encourage them to develop a passion for the mobility industry and gives opportunities to challenge their inherent ability to gain a substantial real life experience. In this context, the section launched an aero design competition called "Manovegam."

The Manovegam competition's structure comprises two different categories: The "regular class" addresses the fundamental understanding of flight, while the "micro class" seeks to address two conflicting aerospace requirements, the desire to carry the highest-possible payload yet simultaneously generate the lowest-possible empty weight.

Manovegam's "virtual" round was held in March at **Siddaganga Institute of Technology**, Tumakuru. The event was inaugurated by Convener Mr. S. Damodaran by lamp lighting. Professionals from various aero companies in and around nearby areas participated as jury members to judge the presentations of the student participants.

Participants included approximately 30 teams from various colleges, not only from Karnataka state but from other parts of India. Those enrolled for the competition showcased their design for the various juries, with the final, flight portion of the competition scheduled for the middle of April at the same venue.

Mr. S. Damodaran, Manovegam Convener, inaugurating the event.

Team Manovegam Virtuals 2017.

SAEINDIA, FISITA announce FISITA World Congress 2018

SAEINDIA and **FISITA**, the international federation of automotive engineering societies, announced that the 37th edition of the FISITA World Congress will take place Oct. 2-5, 2018 at the Chennai Trade Centre. The 4-day international conference, organized by SAEINDIA and FISITA along with the support of SAE International, has adopted the theme, "Disruptive Technologies for Affordable and Sustainable Mobility."

A press conference announcing details of the FISITA World Congress 2018 was held in March at the ITC Hotel in Chennai.

Dr. Pawan Goenka, MD, **Mahindra & Mahindra** and the first Indian to be awarded the FISITA medal of honor, said, "Since 1947, the FISITA World Automotive Congress has been a forum for industry experts, engineers and executives to exchange ideas and discuss trends that will drive the automotive industry forward. India is proud to host this conference in Chennai, organized by SAEINDIA during October 2-5, 2018."

Talking about the theme Dr. Pawan Goenka stated, "In the complex and diversified automotive industry landscape, consumer behavior and preferences dictate the industry transformation. Traditional automobile manufacturers need to be prepared to implement disruptive technology to sustain in the market place. This is likely to result in consolidation and new forms of partnerships among automotive players and other stakeholders leading to collaborative competition.

"Electric and hybrid vehicles, advanced driver assistance, autonomous driving, active safety, connectivity and infotainment are becoming the distinguishing features in the market. Software competency and capability will become the primary prerequisite for automotive manufacturers," he continued. "Disruptive technology is emerging as an important part of research and development in the automotive industry to be an integrated mobility service provider enhancing the value proposition to the end user. The mobility means are getting redefined and people moving from owning a vehicle to owning mobility. India is expected to play a major role to create disruptions and hence this conference is becoming a need of the hour for the automotive world."

Dr. Aravind Bharadwaj, chairman of the FISITA 2018 steering committee,

Dignitaries participating in the FISITA 2018 press conference.

Unveiling FISITA World Congress call-for-papers brochure.

Kickoff of FISITA 2018: signage flag.

added, "SAEINDIA is the biggest affiliate of **SAE International**, having a membership base of over 50,000 and has been associated with FISITA, the association of automotive societies across the world. As a top-notch conference for automotive world, SAEINDIA bidded successfully to move (the conference) from developed countries towards India—the advantage being growth-market India became an ideal destination to host this conference with this appropriate theme."

Mr. N. Balasubramanian, Chairman of the FISITA 2018 Organizing committee pointed out that the conference will attract the automotive fraternity in India and abroad, including 500-plus international delegates and more 1,000 delegates from India. He said the conference is projected to generate more than 500 research papers in latest technology domains to define the path for the future automotive world. In addition, more than 150 exhibitors from across the globe are expected to showcase their technology products. In parallel, the Island of Excellence also is being presented for younger engineering students, the future automotive practitioners.

Technical papers pertaining to the 2018 World Congress theme are welcome. More information regarding FISITA 2018 is available at www.fisita-congress.com.

Industry NEWS

Tata Motors to supply Safari Storme 4x4 to Indian Armed Forces

Tata Motors has signed a contract to supply 3192 units of the Tata Safari Storme 4×4 to the **Indian Armed Forces** under a new category of vehicles known as GS800 (General Service 800). The **Indian Ministry of Defence** had submitted a request for proposal for vehicles with three basic criteria: minimum payload capacity of 800 kg (1764 lb), hard roofs and air conditioning.

The Tata Safari Storme 4×4 from Tata Motors will soon be used by the Indian Armed Forces thanks to a recent contract signed for supply of 3192 units.

Developed in India, the Tata Safari Storme 4×4 has completed a total trial duration of 15 months in various terrains across the country. According to Tata Motors, the vehicle demonstrated "supreme performance in the most demanding conditions with capabilities of coping with extreme on- or off-road terrains."

Tata Motors' foray into defense "is progressing exactly as per the plan," claims the company. The Tata Safari Storme replaces the **Maruti** Gypsy in the 4x4 light vehicle category.

"We are very proud to have received this prestigious order for over 3000 units of the Safari Storme under the newly formed GS800 category," said Vernon Noronha, Vice President, Defence & Government Business, Tata Motors Limited. "Tata Motors has been a leading supplier of mobility solutions to the Indian Armed Forces and this order is a testimony to our partnership with the country's security forces. This variant of the Storme has been modified from the one available for civilians with an upgraded drivetrain and significantly modified suspension."

Introduced in 2012, the Safari Storme offers on-road and off-road capabilities and robust all-round performance. With 154 hp and 400 N·m (295 lb·ft), Tata Motors says the Storme provides easy drivability, swifter response and lower NVH (noise, vibration and harshness). The vehicle also reportedly offers best-in-class ground clearance of 200 mm (7.87 in). The 4x4 variant also features ESOF (electronic shift-on-fly) technology, enabling engagement of the 4x4 or 4x2 mode on the move.

Tata Motors' Defence Solutions offers its customers a wide range of vehicles in the light, medium and heavy category. These include logistics, tactical, armored and specialist vehicles, with lowest lifecycle maintenance cost, supported by the company's pan-India service network, ensuring maximum operational readiness.

Kia Motors signs agreement to build first manufacturing plant in India

Kia Motors recently signed a US$1.1 billion investment agreement to build its first manufacturing facility in India. At a late April ceremony, the automaker completed a memorandum of understanding (MOU) with the State Government of Andhra Pradesh, India to build the new manufacturing facility in the Anantapur District.

"We are delighted to announce that Kia's newest manufacturing facility will be here in Andhra Pradesh," Han-Woo Park, President of Kia Motors, said in a release announcement. "It will enable us to sell cars in the world's fifth-largest market, while providing greater flexibility for our global business. Worldwide demand for Kia cars is growing and this is our latest step towards becoming a leading global car manufacturer."

Construction of the new facility will begin in the fourth quarter of 2017. According to Kia, the assembly plant is expected to begin production in the second half of 2019 and build up to approximately 300,000 units annually.

Kia said it plans to produce a compact sedan and compact SUV especially for the Indian market at the new plant. Industry speculation indicates the compact SUV earmarked for the Indian plant could be a Kia-badged version of the Kona crossover due to soon be launched by Kia affiliate **Hyundai**.

The new plant will occupy around 23 million ft^2 (2.14 million m^2) and incorporate facilities for stamping, welding, painting and assembly. The site will also be home to numerous supplier companies' facilities, says Kia.

India is the fastest-growing major new-vehicle market and the fifth-largest in the world, with more than 3.3 million new vehicles sold in 2016. Forecasts suggest the country will become the third-largest car market by the end of 2020.

A recently released teaser image of the upcoming Kona crossover from Hyundai—a version of which industry is speculating could be built at Kia's new Andhra Pradesh plant in India. (image: Hyundai)

Volvo Buses launches Volvo B8R chassis globally

Volvo Buses has started the global launch of its latest chassis powered by the 8-L Volvo engine. According to the company, the Volvo B8R and B8RLE replace the top-selling Volvo B7R and B7RLE, which saw a production run exceeding 40,000 units and sales in 65 countries. Higher power output, the same low fuel consumption, longer oil-change intervals and a high safety level are some of the features that characterize the new chassis models.

Buses built on the Volvo B8R, one of the two new chassis powered by Volvo Buses' 8-L engine, are already being built in India.

Volvo Buses has started the global launch of its latest chassis powered by the 8-L Volvo engine. Pictured is the Volvo B8RLE.

Marketed in Europe since 2013, Volvo Buses' B8R and B8RBLE will continue in 2017 to be rolled out globally. Buses on the Volvo B8R chassis are already being built in India. This summer several Asian markets are in line such as Malaysia and Thailand, along with Australia, the Middle East, Africa and South America.

"With the introduction of the Volvo B8R/RLE we are reinforcing our global offer with a modern and flexible product range that gives our customers even better scope for operations that boost life cycle cost-efficiency," said Håkan Agnevall, President of Volvo Buses, in a release.

As with their predecessors, the Volvo B8R and the low-entry Volvo B8RLE version are designed to form the foundation for both city buses and intercity buses, as well as tourist coaches and school buses. A robust structure using tried-and-tested components in the chassis and driveline create the prerequisites for high reliability and availability. The buses are also equipped with the Volvo Bus Electronic System, meaning they are factory-prepared for future software upgrades.

The chassis is equipped with the Volvo D8, an 8-L common rail diesel producing 330 hp and up to 1200 N·m (885 lb·ft). Despite a 40-hp (30-kW) increase in power, the new engine is at least as fuel-efficient as its predecessor. The oil change interval has been extended from 30,000 to 40,000 km (18,640 to 24,855 mi) in city traffic, and from 50,000 to 80,000 km (31,070 to 49,710 mi) for buses in long-distance operations.

Designed to meet high demands on driving properties, comfort and safety, the Volvo B8R and B8RLE's standard equipment includes features such as Volvo's electronically controlled disc brakes and ESP (Electronic Stability Program). The Volvo B8R can also be specified with I-Coaching, a system that helps the driver drive more safely and fuel-efficiently by providing continuous feedback.

The company says the chassis will be built in the Volvo Buses factories in Borås, Sweden and Curitiba, Brazil, for local final assembly and bodybuilding.

Lexus debuts in India with a hybrid-focused lineup

Lexus debuted in India in late March when the company unveiled three hybrid models chosen for the Indian market: the RX 450h, ES 300h and LX450d vehicles.

According to Lexus, the choice to focus on hybrid vehicles shows an understanding of the Indian consumer: They have an instinct for luxury, which is coupled with sensibilities around the need for high-performing yet eco-friendly vehicles. From visually captivating exterior designs and interior cabins that exude luxury and attention to detail, to the environmentally conscious hybrid drive technology, Lexus says it will deliver to the highest expectations of Indian luxury consumers.

The models will be available at guest experience centers located in New Delhi, Gurgaon, Mumbai and Bangalore. Additionally, after-sales service facilities will also be available in Chandigarh, Hyderabad, Chennai and Kochi.

"How India experiences luxury is evolving with its affluence," Lexus India Senior Vice President, Akitoshi Takemura said, speaking about Lexus' plans for India. "Lexus will be providing the Indian consumer with an amazing experience through our vehicles, our service and through any interaction with our brand. We are excited about what we can bring to the luxury market in India, where we see opportunities mapped to the remarkable growth the country is experiencing. This is just the beginning—we look forward to bringing more exciting products to India in the future."

The first-ever Lexus India vehicle lineup reflects the signature style and quality on which the legacy of the Lexus brand is built, and is an example of Lexus' dedication to creating cars with exciting, emotional designs and exhilarating performance.

The all-new Lexus LS made a surprise appearance in a sneak preview at the end of the unveiling. It will be available in 2018.

"The original LS rivaled the very best luxury vehicles. We had big dreams about what a luxury vehicle could be. Those dreams were realized with a vehicle and guest experience that disrupted the luxury automotive industry," Lexus International President Yoshihiro Sawa said in a release.

The first Lexus LS was, and continues to be, a game-changer for the luxury automotive industry, and Lexus supported that vehicle by setting and maintaining new standards for customer service and satisfaction. Lexus plans to do the same in India with dedicated relationship managers and 24/7 guest call centers.

The ES 300h is one of three hybrid models now available from Lexus in India.

TECHNOLOGY Report

AUTOMOTIVE PROPULSION

Targeting 40% BTE with advanced VCR

Nissan's announcement at the 2016 Paris Motor Show that it will bring a variable-compression-ratio engine to production in 2018 (see AE November, 2016, p. 6) energized those in the advanced-ICE development community who also have VCR technologies in the works. Varying compression ratio according to load, speed and other parameters is a significant 'lever' that has yet to be pulled, in series-production volumes, to further optimize 4-stroke efficiency.

"The automakers have picked the low-hanging 'fruit' and are now climbing higher in the technology 'tree' to pick what will enable them to achieve the 2025 CO_2 regulations," explained Henri Trintignac, Chief Executive Officer at **MCE-5 Development**. The Lyon, France-based engine-tech company has been focused on its unique VCRi system for 17 years and has documented its progress via many **SAE** technical papers and presentations over the past decade. Its first development contract, signed in 2015, is with China's Dongfeng Motor.

"The customer is interested in an engine family covering from 70 kW up to 200 kW. We do that with only three displacement variants and one bore, one stroke. Two-, three- and four-cylinder engines," he said.

MCE-5's system uses a dedicated cylinder block, cranktrain and actuators to provide continuous compression ratio control, ranging between 8:1 and [geometric ratio] 18:1 to each cylinder (see http://articles.sae.org/6043/). Trintignac, a former **Valeo** powertrain systems executive, said the turbocharged VCRi can switch from minimum to maximum compression ratios in less than 100 ms.

"We can vary the compression ratio infinitely and we can go from 15:1 to 18:1 in just one combustion cycle," he told *Mobility Engineering*. Running at part load, the effect is to minimize BSFC and maximize the "sweet spot" area on the fuel consumption map.

The company now is demonstrating the thermodynamic synergies of combining VCR with infinitely variable valve actuation. The aim is to enable enhanced Miller/Atkinson-cycle operation and thus improve part-load efficiency by reducing heat and pumping losses and optimize the compression-expansion ratio. With this combination of technologies, the inlet valves are open only during half of the compression stroke, so the effective compression ratio is in the range of 10:1.

"We can move three points of compression ratio in less than two cycles," Trintignac reported. "And yes, we spend a lot of time on controls development!" He said 3D combustion simulations [conducted with IFP-C3D, a parallel solver] correlate closely with data from single-cylinder bench work. The tests show an indicated efficiency increase of 12-13% between 10:1 and 18-20:1 compression ratios at low loads, with BMEP less than 8 bar, he said.

The MCE-5 development team is targeting 50% brake thermal efficiency (BTE) by 2030, using a step-phase process. "For the first application by 2020, we are aiming for 40% BTE, 260 g/kW," he said. "Next, we can increase the BTE to 44-45% by 2025" then beyond through methodical technology steps.

Refinement of the VCR mechanism and controls continues while combustion engineers play with geometric compression ratios as high as 23:1. Work proceeds on high rates of external cooled EGR (up to 60%)—heavy charge dilution described by Trintignac as HCCI (homogeneous-charge compression-ignition)—aided by a super-high-energy ignition necessary for stable and rapid combustion. Engine-heat recovery strategies also are under review.

CEO Henri Trintignac: "We can vary the compression ratio from 15:1 to 18:1 in just one combustion cycle." (Lindsay Brooke photo)

The MCE-5 VCR mechanism includes the guided piston and combustion rack on the left side and the 'control jack' and control rack on the right side, activated by inertia and gas forces. The connecting rod big end is at bottom; it links to the central gear wheel in the center.

The new ignition system is dubbed SSP, or Stratified Spark Plug. Trintignac would say only that it was developed internally and it's not a plasma-based system. He claimed SSP can deliver 1 joule of ignition energy, compared with the 50 millijoules of a conventional ignition system.

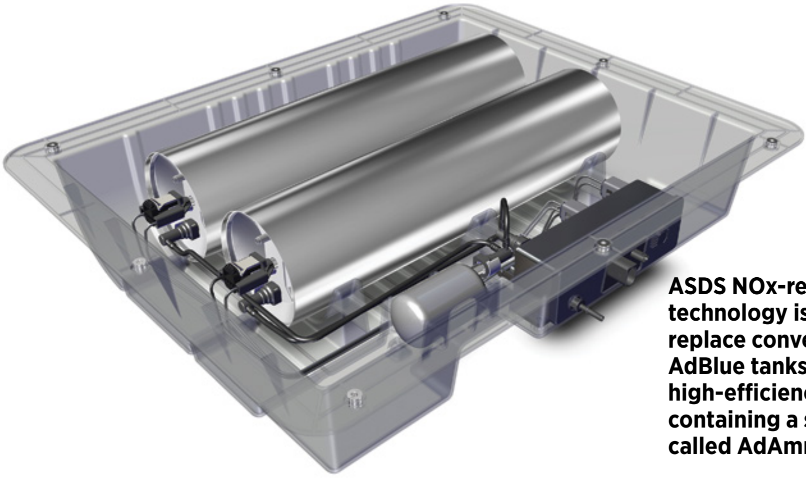
Trintignac invites OEM engineers to Lyon to drive MCE-5's demo vehicle and find out more. "To the industry it's all about cost-to-benefit ratio—how many euros or dollars they have to spend to save each gram of CO_2," he noted. "Hybrid 48-volt systems save almost 15 grams on the WLTP cycle and we're in the same range, 10-15 grams.

"But the 48-volt hybrid costs 60 to 70 euros per gram saved. Our VCR costs 30 euros per gram."

Lindsay Brooke

TRUCK & OFF-HIGHWAY EMISSIONS

Faurecia targets NOx reduction at lower exhaust temps with lightweight cartridges



ASDS NOx-reduction technology is designed to replace conventional DEF or AdBlue tanks with lighter, high-efficiency cartridges containing a solid material called AdAmmine.

The Ammonia Storage and Delivery System (ASDS), developed by **Amminex**, has demonstrated an ability to nearly eliminate nitrogen oxide (NOx) pollutants from diesel engines. Called a "new generation" of NOx reduction technology, ASDS is designed ultimately to replace conventional tanks containing a diesel exhaust fluid (DEF) or AdBlue with lighter, high-efficiency cartridges containing a solid material called AdAmmine, also developed by the Danish company.

In December, **Faurecia** acquired a 91.5% share of Amminex, to intensify the development of ASDS technology for both commercial vehicles and passenger cars. Faurecia has worked with Amminex since mid-2009 and previously owned 42% of the company.

"ASDS functions at lower exhaust temperatures, even in winter driving conditions. Moreover, for equivalent quantities of ammonia, ASDS requires only half the volume of that required for AdBlue," said Christophe Bouly, CTO of Faurecia Emissions Control Technologies.

One 11-L ASDS cartridge is comparable to 20 L of AdBlue/DEF.

Selective catalytic reduction (SCR) using liquid reductant is the most widely-used method to reduce NOx emissions. Bouly said ASDS has the potential to become "the new world standard for NOx reduction."

AdAmmine consists of ammonia adsorbed in strontium chloride salt in a solid form. AdBlue, currently the most widely-used NOx-reduction fluid, can be injected into the exhaust stream only at exhaust temperatures above 180°C (356°F), while ASDS has the ability to optimize SCR in lower exhaust temperature ranges—from 140-180°C (284-356°F), according to Faurecia.

The ASDS cartridges can be stored or transported safely at temperatures ranging from -40 to +80°C (-40 to +176°F).

How it works

The ASDS system begins releasing pure ammonia in gaseous form into the exhaust line within a few minutes after engine start-up. Faurecia describes how the system works: At ignition of the engine, the start-up unit is electrically heated. In less than 2 minutes, the temperature reaches 60°C (140°F) and the salt releases pure ammonia on demand. The ammonia is routed under low pressure to the control unit, then an electric valve pilots the distribution of ammonia directed to the exhaust stream.

While the start-up unit is operating, one of the main cartridges that is larger in size is heated. When the main cartridge reaches its operating temperature, it takes over the release of pure ammonia from the start-up unit. When the engine is turned off, the distribution of the ammonia is stopped. As the temperature drops, the pure ammonia returns to its solid form and is again stored in the salt.

ASDS has been proven to reduce NOx emissions by up to 85-99% on more than 15 million km (9.3 million mi) of real-world use with buses. This compares to an average 32% NOx reduction with AdBlue in the same city-driving conditions. These findings are the result of monitoring hundreds of ASDS-equipped buses in Copenhagen and London, and comparing them with buses using AdBlue on the same streets.

Demonstration vehicles also are running in Germany, China and Korea. In total an estimated 400 vehicles are in operation today, with the total fleet exceeding 25 million km (15.5 million mi). Faurecia has supplied more than 25,000 refilled cartridges, roughly equivalent to 500 ton of DEF/AdBlue.

System cost on the vehicle is comparable to a DEF system, Dave DeGraaf, President of Faurecia Clean Mobility North America, told *Mobility Engineering*.

"ASDS has no injector and uses a simple steel nozzle. The ammonia flows in through a non-heated tube," he explained. "Unlike the deposits left in the exhaust system from the liquid urea used in AdBlue/DEF systems, ASDS uses gas that does not leave deposits. This ultimately will allow a fleet owner to stay with diesel technology longer and reduces the need to refresh the fleet frequently."

Potential off-highway application

Faurecia showed the Amminex solution for commercial vehicles at the 2016 Paris Motor Show, as well as an ASDS system in a new format for diesel passenger vehicles. The company also is investigating other applications of ASDS, including for off-highway vehicles and high horsepower (HHP) engines used on ships and vessels.

"This is something that is still in development," DeGraaf said. "We believe the same commercial-vehicle ASDS system that is used on buses and trucks today can be used for off-highway and marine when the engines are comparable in size. We are still exploring specific solutions for larger engines using the same core technology."

For passenger cars, engineers have created a smaller package for ASDS that fits in the trunk or any other available space. Faurecia proposes offering a full line-up of cartridge sizes, from 1L to 11 L. The smaller cartridges can be changed

For equivalent quantities of ammonia, ASDS requires only half the quantity required for AdBlue, according to Faurecia.

by the driver in plug-and-play fashion.

What kind of weight savings are possible? "Light duty [vehicles] that currently use the 17-L AdBlue system would see a 30-40% weight reduction," said DeGraaf. "In commercial vehicles that currently use the 40-L AdBlue system, the weight reduction is slightly lower at approximately 20%. Preliminary results also indicate that ASDS could potentially optimize fuel consumption in the range of 2%."

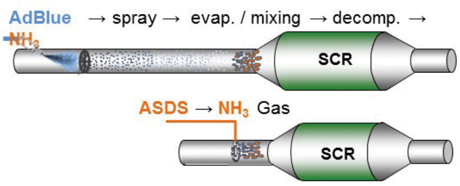
Faurecia says the compact ASDS cartridges will be available for post-2020 passenger vehicles.

Ultra-low NOx regulations

Ultra-low NOx regulations are likely coming in the U.S. for heavy-duty on-highway engines beginning in model year 2024, lowering the allowable limit from 0.2 g/bhp-hr to 0.02 g/bhp-hr. DeGraaf believes ASDS can help achieve these targets with reduced impact on fuel economy.

"In-use performance in city driving is of high interest for the next step in U.S. legislation, in particular **CARB**," he said. "ASDS can help enable high performance in real driving conditions—particularly in cities—without the use of exhaust heating strategies that are needed in DEF injection."

In Copenhagen, for example, estimates indicate that buses have contributed to as much as 10% of the NOx pollution, DeGraaf noted. Faurecia's data suggests that the 261 ASDS-retrofitted buses there have already collectively removed more



ASDS reportedly achieves three to five times better NOx reduction in city driving with no CO_2 increase (cold engines) and 20% better NOx reduction on highways (hot engines).

than 45 tons of NOx from the air.

"It has a positive impact on both fuel economy and CO_2," he added. "Exhaust heat management typically consumes 3-5% of extra fuel/CO_2 during light to medium load conditions. Since ASDS is not a liquid, it does not need catalyst heat management to function properly, which saves that fuel/CO_2 consumption."

Amminex employs 50 people at its headquarters in Søborg, near Copenhagen, and its 6500-m^2 production facility in Nyborg. Annika Isaksson, Amminex CEO, and Tue Johannsen, CTO and inventor of the ASDS technology, have remained in their positions following the Faurecia acquisition, to help lead the technology's new stage of development.

Johannsen and other Amminex experts wrote an **SAE** Technical Paper (2008-01-1027) in 2008, in which they offer an initial look at the storage concept, including system design, performance data and implications for vehicle integration.

Ryan Gehm

AUTOMOTIVE SAFETY

Euro NCAP to adopt autonomous vehicle ratings

The Euro New Car Assessment Program (NCAP) safety-test rating will establish a separate category for autonomous vehicles, but there is not likely to be one for cars that are claimed to protect all occupants from serious injury or death. And while there is currently little sign of a harmonized engineering and cost saving global test system, there may be an opportunity in the future, reckons Matthew Avery, Director of Insurance Research at **Thatcham Research**, which carries out Euro NCAP tests in the U.K.

According to Michiel van Ratingen, the Euro NCAP General Secretary, there has been a "slow down" in new safety systems' progress. According to Avery, this isn't due to lack of ideas.

"We continue to see significant progress," he told *Mobility Engineering*. Development of passive safety systems (seatbelts, belt tensioners and airbags) has plateaued; industry penetration of these innovations has resulted in a 63% reduction in killed and serious injured (KSI) over the past 20 years. Meanwhile, there has been a dramatic acceleration in 'active' safety technology, which works hand-in-hand with the passive safety net.

"Ultimately, prevention is better than cure," Avery said. "When it comes to investment and cost benefit, there's much more that can be done to prevent the crash entirely than there is to improve how a car behaves during a crash."

Harmonizing Euro and U.S. standards

Recently the latest generation **Ford** Mustang scored only a 2-star result in Euro NCAP tests, leading some safety experts to amplify the call for global test harmonization. They argue that the present individual regional standards make for engineering complexity, increased costs and an element of confusion.

"Unnecessary engineering complexity could be looked at in a different way, as an opportunity for increased engineering robustness," Avery observed. "Having different tests in Europe and the U.S. delivers a more robust end product because we have to be able to accommodate different crash types.

How crash results used to be and how they are now: Above, a current Honda Jazz; below, a 1997 Rover 100 undergoing comparative Euro NCAP tests. What will SAE Level 4 and 5 vehicles look like after they complete the new NCAP testing?

Thatcham's Matthew Avery says completely avoiding death and serious injury won't be a standard which comes into Euro NCAP testing.

He said the U.S. does not test differently as a result of idiosyncratic driver behavior; rather, it designs for a very common crash situation.

"What we do is not unique to Europe per se, but it is also in response to one of the most common types of injurious crash. If you put the two together, you have a more robust system," he noted. Does that mean it's more costly for OEMs? Yes. But it also means that the engineering is more robust for the consumer.

Presently there is little or no global harmonization of the NCAP standard; the tests reflect individual markets and prominence of specific types of vehicles. So for Europe to have to engineer for large pickup trucks—or for the U.S. to engineer for A-segment city cars—wouldn't be right for either market, Avery asserted. He noted that in 2008 such a scenario actually was played play out in Euro NCAP testing when a series of U.S.-style pickup trucks performed poorly as a group.

In the future, however, there is an opportunity for harmonization and that is already in process to some degree. "The Autonomous Emergency Braking (AEB) testing we developed at Thatcham Research, for example, is now part of Euro NCAP's overall testing regime and has also become an essential part of the U.S. testing system," he explained. The process exists for pedestrian, car-to-car, city and inter-urban AEB, along with a new Global Vehicle Target test also co-developed by Thatcham engineers.

"Harmonization ideally needs to come at the embryonic ideas stage," Avery stated.

Separate 'star' rating for autonomous vehicles

Will there be a separate "star" rating system for autonomous vehicles—and are there likely to be new safety technologies for autonomous vehicles that would allow them to achieve maximum star rating?

"We are likely to see a separate rating beyond the 5-star system, to help drivers understand how well the autonomous system of any given vehicle performs in relation to others," Avery noted. At present, autonomy is about braking and steering assistance, for example Emergency Lane Keeping (ELK), a subsystem of the wider testing program. He believes that because 93% of accidents are a result of human error, it is possible to eradicate the human error element completely through the proper integration of ADAS sensors and control algorithms.

Steering intervention is a safety technology that Avery believes is likely to help vehicles achieve maximum safety ratings. "ELK will be a feature of testing for 2018 and by the early to mid-2020s we will be looking at Autonomous Emergency Steering (AES)," he noted.

These systems are required for true vehicle autonomy and they introduce a whole host of new opportunities to avoid the crash. There are occasions where the two operating in tandem are better, Avery said, and others when they operate individually to avoid an accident.

While Volvo is aiming for occupants of its post-2020 models not to suffer death or serious injuries, what about the entire industry achieving such a standard? Would this goal likely become a Euro NCAP requirement for a maximum star rating?

"Avoiding death or serious injury completely will not be a standard which comes into Euro NCAP testing," Avery asserted. "Other vehicle manufacturers however will be keeping a keen eye on **Volvo** and how successful it has been, especially where a marketing advantage can be gained."

However, Euro NCAP won't look at that because it would require a huge, well orchestrated analysis of pan-European crashes. "It also fails to account for "acts of God" which are beyond the means of any safety technology, passive or active," he said.

Stuart Birch

AEROSPACE MANUFACTURING

Norsk gives Boeing manufacturing edge with first 3D-printed titanium components

Norsk Titanium AS—which has been researching and developing its RPD (rapid plasma deposition) process for over 10 years—says it can produce titanium components that can cost from 50 to 75% less than other equivalent components. Its process involves feeding room-temperature titanium 6-4 wire into a plasma arc created by a pair of torches in argon gas environment. The titanium temperature is raised by thousands of degrees and then is robotically printed as a liquid by a robotic depositing arm. The titanium solidifies instantly after being deposited. The component is rapidly built up in layers in a closed-loop process and requires very little finish machining.

The system itself, a MERKE IV RPD machine, bears a resemblance to a standard computer numerical control (CNC) machining center—with a plasma arc instead of a spindle. Norsk President and CEO, Warren Boley stated that the MERKE IV RPD machine "can print 20 tons of titanium per year," and that it's "a game changer in terms of being able to produce aircraft quality titanium parts."

Inside a Norsk MERKE IV RPD machine.

An unfinished titanium structural component printed by the Norsk RPD process (left), the same component after first stage machining (center), and the final version after finish machining (right).

This past April, Oslo-based **Norsk** announced that it will be producing via RPD 3D-printed structural titanium components for the **Boeing** 787 Dreamliner. Boeing designed the components and collaborated closely with Norsk throughout the development process. To certify these initial structural components on the Dreamliner, Boeing and Norsk undertook a rigorous testing program with **Federal Aviation Administration** (FAA) certification deliverables completed in February. Norsk is the first supplier for Boeing's high deposition rate material specification.

"We are always looking at the latest technologies to drive cost reduction, performance, and value to our customers and Norsk's RPD capability fits the bill in a new and creative way," said John Byrne, Vice President, Airplane Materials and Structures, Supplier Management, Boeing Commercial Airplanes.

Norsk claims that the production cost is less than that of legacy forging and manufacturing techniques where billets of titanium are machined into components.

"You can take a 200-lb forging and produce a 20-lb part," said Boley. "We can print 30 lb of material to produce a 20-lb part." Producing a 200-lb billet and machining it down to a 20-lb component typically requires a lead time of 55 to 75 weeks. These same components can be created via RPD and machine finished within 2 to 3 hours.

Because of the significant reduction of waste and machining energy inherent in their additive process, Norsk claims up to 75% cost and time savings.

With an estimated 1000 titanium components in a Boeing 787 that can be manufactured using the RPD process, Boley stated that, "We think we can save $2500 per part; that's $2.5 million per aircraft. At 144 aircraft a year, that's $360 million. That kind of saving is revolutionary."

Norsk also takes note of the environmental impacts that its RPD process brings as well. By reducing the amount of scrap titanium (approximately 40 lb of scrap to 1 lb that sees flight), the process also reduces the amount of ore that must be mined and processed.

The Dreamliner RPD components—as well as Norsk Titanium's MERKE IV RDP machine that produced them—will be on display at the International Paris Airshow, Le Bourget in June.

William Kucinski

OFF-HIGHWAY POWERTRAIN

At ConExpo, Isuzu Motors announces heavy-duty natural gas engine for off-highway

Isuzu Motors America used the ConExpo-Con/Agg 2017 stage to announce its intention to produce a dual-fuel capable (natural gas and propane) off-highway engine by mid-2018, leveraging its already-in-production on-highway CNG truck engine.

The 4.6-L 4HV1 engine, on display for the first time at the Las Vegas event, will have an expected maximum rated output of 81 hp (60.5 kW) at 1800 rpm and torque rating of 247 lb·ft (335 N·m) at 1400 rpm when operating in natural gas mode.

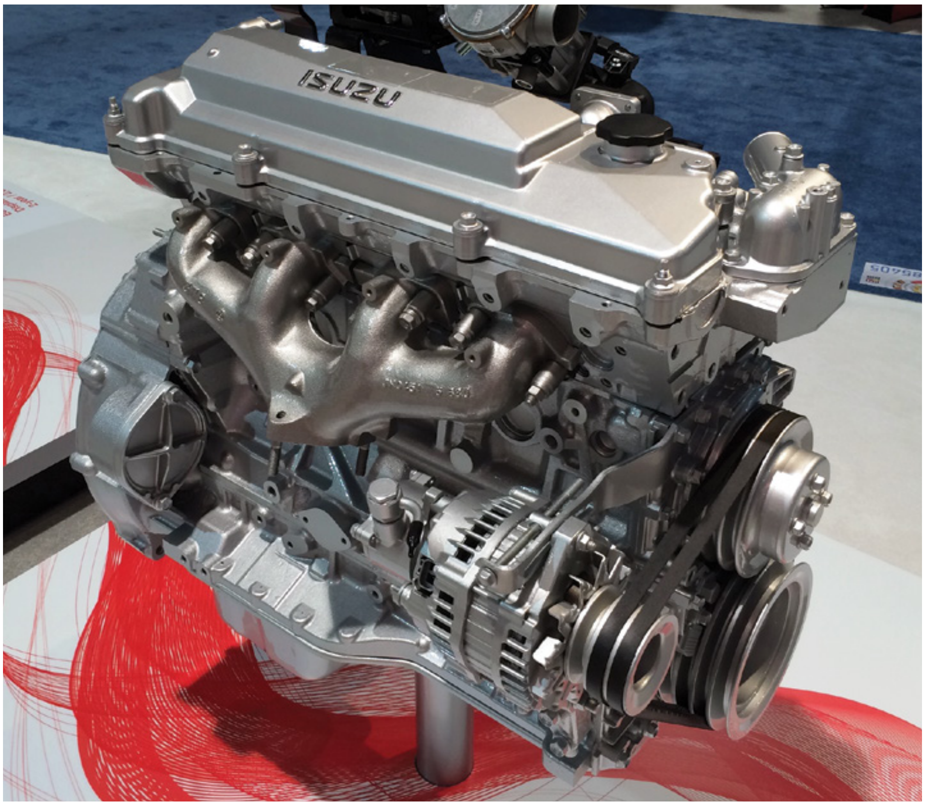
"We've studied the market for about two and a half years now and felt that it'd be a good fit for us to expand into the gas market [for off-highway]," Ken Martin, director of sales & service for the Powertrain Division of Isuzu Motors America, told *Mobility Engineering*. "We feel this engine is going to fill a hole that's out there. And we have a lot of experience and field usage already with the gas engine because the base engine model that we're using has been running since 2012 in our CNG truck market."

The truck version is used in the U.S. and some Asian markets. "That's one of the reasons why we'll be able to come to the market competitively priced: a lot of the R&D has already been completed," he said.

Since it's a "gasified" diesel engine design, the company is confident in the engine's durability and reliability, compared to some competitors that base their gas variants on gasoline engines, Martin said.

Some changes were necessary compared to the base diesel engine. "With gas there isn't any lubrication in the fuel, so you have to look at hardened seats, hardened valves. You have to lower compression ratio and change the piston rings, to name a few things. But again, we've already experienced that in real life on the truck side."

4HV1 employs a fuel system from **IMPCO**, which also supplies the system for the on-highway model. Durability testing of the fuel system on the new engine is currently under way.



The 4.6-L 4HV1 natural gas engine, on display for the first time at ConExpo in March, is suitable for various industrial and mobile applications including water pumps, generators, and forklifts. (Photo by Ryan Gehm)

4HV1 employs a fuel system from IMPCO, which also supplies the system for the on-highway model. Durability testing of the fuel system on the new engine is currently under way. (Photo by Ryan Gehm)

"We're programming the ECU to run off of natural gas and LPG, so with the flick of a switch you can switch back and forth," he said.

Isuzu Motors believes the new gas engine will find a fit in various industrial and mobile applications including pump markets, generators, and forklifts.

Additional specs for the 4-cylinder vertical inline engine include:

- Bore x stroke: 115 x 110 mm
- Length: 35.4 in (900 mm)
- Width: 22.9 in (580 mm)
- Height: 38.2 in (970 mm)
- Dry weight: approx. 815 lb (370 kg).

"After we launch the 4HV1 we'll see how it goes," Martin said, referring to possible next steps for a natural-gas product range. "We're looking at launching a 6-cylinder version, a higher kW rating, as well."

The engine was well-received at ConExpo, Martin said. Field testing with interested customers will begin this April.

Ryan Gehm

TRUCK & OFF-HIGHWAY POWERTRAIN

Alternative powertrain tech, connectivity hot topics at ICPC 2017

Focusing on technologies and strategies impacting truck and bus, agricultural tractors, and construction machinery, the biennial AVL International Commercial Powertrain Conference (ICPC) organized in cooperation with **SAE International** was held in Graz, Austria from May 10-11, 2017. Experts from each of these sectors shared their insights related to the 2017 event's overarching theme: CO_2 reduction and innovations to improve operating efficiency. Dr.-Ing. Marko Dekena, Executive Vice President, Global Business Development, Sales and International Operations Powertrain Systems, AVL List GmbH, recently spoke with editor Ryan Gehm about some of the strategic and technical issues discussed at the conference.

"The amount of CO_2 reduction [connectivity/ADAS] technologies will achieve cannot yet be estimated, but it will certainly be higher than technical measures on the powertrain alone will enable," said AVL's Marko Dekena.

Electrification was a major topic of the event across all three segments. What is the outlook for electrification in each of them?

Let's first define "electrification" because it covers a huge field of technologies: hybridization (mild, full, plug-in), battery electric vehicles (BEVs), and fuel cell electric vehicles (FCEVs). Most likely this is also the introduction sequence for eventual applications of these technologies. The extent to which these technologies will be applied depends on the kind of vehicle, application and the main operating conditions—so, you see, it is quite complicated.

Secondly, we need to be clear how "CO_2 emissions" is defined: tank-to-wheel, well-to-wheel or cradle-to-grave. The results are completely different. Personally, I would prefer the holistic view from cradle-to-grave, because it is the only correct way to reduce CO_2 emissions. However, it is the most difficult approach due to lack of data in the various areas at present. To make it a little easier, let's take tank-to-wheel—this is also the way most publications are dealing with this matter.

Light-duty and some **medium-duty trucks**, operating in urban traffic, are suitable both for hybridization and BEV operation, maybe in the long term also for fuel-cell operation. The CO_2 saving potential with city hybrids is in the range of up to 20%. But instead there seems to be a new trend towards BEVs. And here the amount of CO_2 reduction (tank-to-wheel) is much higher, but the reduction, when you regard well-to-wheel, depends very much on the electric power source—where does the power come from? If you take, for instance, today's power mix of China there could be no well-to-wheel reduction at all. If all electric power comes from renewable energy sources, the well-to-wheel CO_2 reduction will be much higher. Very much the same can be said for city buses.

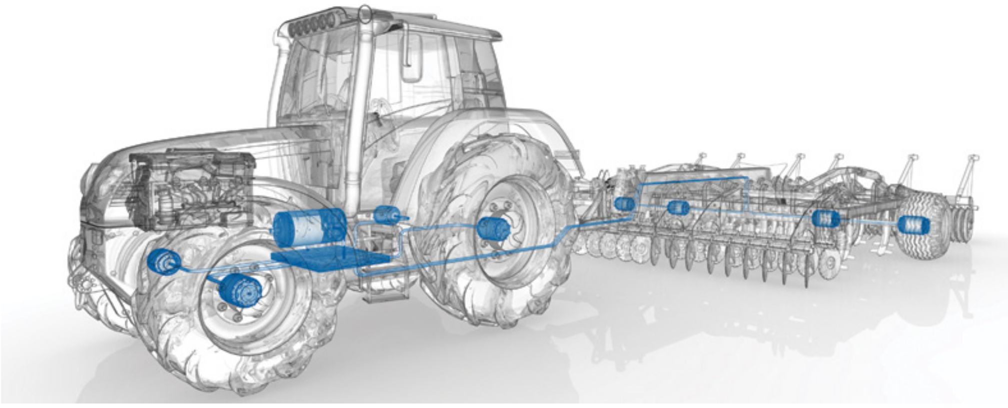
Heavy-duty long-haul trucks are different. They run typically 150,000 to 200,000 km per year and therefore every percentage point of fuel / CO_2 savings makes a big difference. Hybridization in combination with downsized diesel engines makes a lot of sense and can achieve savings of 8 to 10% depending on the topography. Waste heat recovery can save another 3 to 5%. I can hardly imagine HD trucks as BEVs. Batteries are still—even in a theoretically very advanced status—by far too heavy and costly. Trucks need to earn money and so every kilogram of dead weight / lost payload reduces efficiency and profitability. If at all, in the longer term I could imagine a fuel-cell-powered long-haul truck.

Let's talk about **agricultural tractors**—I mean real farming tractors, not derivatives such as street sweepers, utility tractors for communities, etc. For the hard and sometimes extremely diverse work that tractors do, electrification can save a lot of CO_2 and consumables when applied to the various implements. The diesel drives a generator which supplies power to the PTO and/or to the implements which now have no mechanical connection to the engine anymore but are driven by electric motors. This makes a lot of sense—the whole system is much more efficient and flexible for different applications.

Finally, let's consider **construction equipment**. BEVs may be suitable for very small equipment for shorter operations, very much depending on the operation purpose. Hybridization is the choice for all vehicles operating under heavily changing load cycles and braking. Here the electric motors can assist transient behavior by boosting acceleration and acting as generators during braking, thus feeding power back to the battery, which can then be used for the next acceleration. Simulations we made in AVL, for example, for wheel loaders proved fuel / CO_2 savings in the order of 10-15%.

How much is shared technology?

I think quite a lot, both in hardware and control software. However, the huge amount of different vehicles, applications and operation conditions makes it very difficult to find the best solution in every case. Finding the "right" combination of diesel engine, transmission, electric devices, storage system and control system is



For ag tractors, the diesel engine can drive a generator that supplies power to the PTO and/or the implements which have no mechanical connection to the engine, but instead are driven by electric motors. "This makes a lot of sense—the whole system is much more efficient and flexible for different applications," said Dekena.

an enormous challenge in all the discussed application areas, even if the individual components are known or even the same. Here, full system simulation comes into the game, an area where AVL has collected significant experience in the last 10 years. All tools and procedures to simulate even very complex systems in any real operating condition have been developed, proven and are ready for use.

Likewise for operator efficiency, connectivity and ADAS appear to be major trends that cross the segments.

Basically, there is a huge potential to increase the efficiency of all kinds of commercial vehicles by applying connectivity, Big Data and autonomous driving. Although there currently seems to be a hype in all areas, it will take many years to make use of these technologies on a large scale. There are still too many open issues like standardization, legal issues, national and international rulemaking, safety and technical issues, insurance and liability questions and many more. You may know that larger agricultural tractors have for a number of years been operating autonomously or at least partially autonomously, enabling precision farming. The vehicle or several vehicles at once are controlled by GPS not only for precise tracking but also for soil detection and optimized fertilizer output control.

Trucks and buses will be the next category of vehicles to apply this technology, first in enclosed areas and later also on highways, in the simplest form of platooning. Also, logistics control will enable a major improvement of vehicle and operator efficiency by largely avoiding 'empty drives.' The ongoing intensive activities in the passenger car area will definitely also pave the way for commercial vehicles. But it is clear that every vehicle needs specific adaptations according to its operating conditions. I can hardly imagine driverless vehicles but I am sure that the tasks of the driver or operator will change and result in higher efficiency.

I see big advantages in the operation of construction machines, especially when it comes to larger construction sites with many different machines and vehicles involved—the so-called site management. By optimizing and linking the various and manifold operations, waiting times and inefficient travels can be avoided. Intelligent condition monitoring and preventive maintenance and service of the vehicles will help to further reduce unplanned downtime to a high extent.

The amount of CO_2 reduction these technologies will achieve cannot yet be estimated, but it will certainly be higher than technical measures on the powertrain alone will enable. The challenges mentioned initially have to be solved across all applications, but everyone will have their own specific solution. Thrilling times ahead of us!

Which upcoming emissions regulations are top of mind and pose the greatest challenges to engineering efforts?

It's still the well-known emission of NOx, hydrocarbons, and particulates. We have to envisage even tighter limitations beyond EU6 and Stage V together with changes of the measurement procedures—with the keywords Real Driving Emissions and In-Use Compliance. The real future challenge is the combination of tough CO_2 / fuel consumption limitations in nearly every part of the industrialized world with further drastically reduced NOx limits. Whatever we do to reduce the toxic emissions will basically contradict CO_2 and fuel consumption reduction. How to reduce emissions in general is well known in the meantime—the technologies to be applied are available and proven. They need to be refined for the various applications, which is a tremendous amount of work but the road map is rather clear. This applies for all vehicle segments from passenger cars to construction equipment within different time frames.

However, for the time being the recent new proposals or intentions of the U.S. Environmental Protection Agency (**EPA**) and the **California Air Resources Board** (CARB) create a lot of headaches for engineers. Fuel consumption of HD truck engines has to be reduced until 2027 by further 4% compared to model year 2017, according to EPA. CARB even wants to cut fuel consumption figures by 8% within the same time frame combined with a further NOx reduction of 90% compared to MY 2017! In addition, the new EPA proposal calls for a 20% reduction of fuel consumption of the complete truck—this is a quite new and extremely challenging situation. And it is very likely that similar restrictions will one day be transferred to the non-road sector. AVL is currently successfully working on solutions—how modern powertrain technologies can be combined in a cost-effective way to meet those tough regulations.

What other alternative powertrain technologies can make a big impact in this regard?

Certainly there is still improvement and refining potential in conventional powertrains including transmissions. This is ongoing and business 'as usual.' Fuel cells are back again after the hype in the late '90s. As said already earlier, I do see a good chance longer term for application in long-haul trucks. When it comes to fuel cells it is mandatory to make the view from cradle to grave. Although the fuel cell itself offers a rather high efficiency, there are significant losses to be taken into account which happen during production and transport of hydrogen—in the end there might not be an efficiency advantage for many applications. Of course, infrastructure issues will be a major hurdle, especially when it comes to agricultural tractors and/or construction machines. I cannot imagine a hydrogen filling station somewhere on a construction site in the middle of nowhere. And of course, the price question has to be answered.

I do see much more potential in alternative fuels, but not those discussed in the past. I see a thrilling potential in synthetic fuels or so-called e-fuels generated from renewable CO_2-neutral power, and hydrogen synthesis making use of CO_2 from power plants and other CO_2-generating factories—or even extracted from ambient air. The basic technologies and processes are known and according to recent publications even the costs could be reduced significantly. I do hope that all involved industries take this path seriously into account as it opens a much more effective way by which conventional diesel (and also gasoline) engines could be used further on. It would be a great achievement, because these kinds of alternative fuels would also have an immediate effect on the whole existing engine population.

What's your view of waste heat recovery? Many say it's not cost-effective and becomes less important as engine efficiency is optimized.

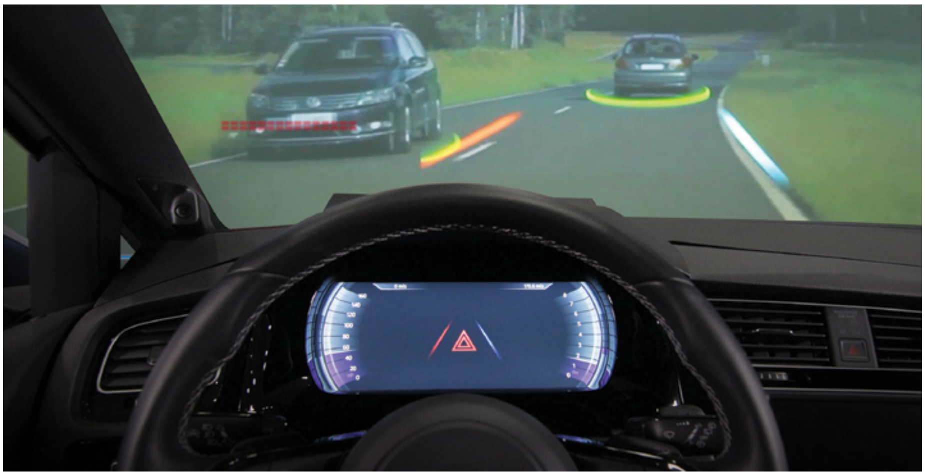
I do not agree at all! Even if engine efficiency is increased there will still be a waste of 20% of the fuel energy, so it is worth exploiting that potential. AVL and others have proven a fuel consumption reduction by WHR in the order of 3-5% in real long-haul trucking. These trucks run about 150,000 km/year and consume about 40,000-50,000 L of diesel. Depending on the actual fuel price, savings in the order of 2000-3000 €/year are realistic. This means that the payback period could be less than 2 years. Of course, it depends very much on the application, the topography the vehicle is driving and the fuel price. WHR is still under development and I expect further efficiency improvements to come. WHR makes a lot of sense for applications like long-haul trucks, coaches or marine applications in which no extra energy is needed for cooling fans to get rid of the heat during WHR operation.

Ryan Gehm

Read the complete transcript of this interview at http://articles.sae.org/15305/.

AUTOMOTIVE ELECTRONICS

Visteon tests augmented reality HUD for Level 4 autonomy



A halo around an oncoming car and other graphic overlays are shown on the AR HUD in Visteon's VW Golf demo vehicle, which also has an exterior forward-facing camera and two driver-facing cameras.

Augmented reality (AR) head-up displays are emerging as critical equipment for **SAE** Level 4 autonomous driving, where the operator must completely trust that the vehicle's ADAS sensors and cameras are monitoring and accurately recognizing its surroundings.

Mobility Engineering recently experienced a proof-of-concept demonstrator vehicle fitted with **Visteon**'s latest AR HUD system, at the supplier's Van Buren Twp., MI, headquarters. On the 2015 VW Golf R's windshield, graphics are superimposed over the driver's real-time sight line to indicate objects detected near the vehicle's path. The system also displays relevant driver information, such as lane departure warning, and navigation guidance.

With a 10 x 4-degree field image, the windshield AR HUD is nearly twice the size of those used on current production vehicles, company engineers claimed. Images are projected 33 ft (10 m) from the driver's eyes in comparison to the typical 6.5 ft (2 m) distance.

The system was designed to display sensor information "in a relevant and comprehensive manner in the driver's field of view," noted Patrick Nebout, Director of Advanced Technologies. He noted that the demo vehicle was developed by engineers at Visteon's technical center in Cergy, France.

Driver-facing interior cameras, located in the A-pillar and the rearview mirror, monitor the operator. They trigger audible and visual alerts to rouse a distracted driver, explained Mike Eichbrecht, a member of Visteon's North American technical sales group. "For instance, if you're looking down at your cell phone, an audible tone and LEDs lets you know that something in the car's vicinity, such as a bicyclist beside the road, needs your full attention," he said.

Nebout believes that an AR HUD will be the fastest, easiest and most effective interface for informing the driver of what the vehicle's sensor array has detected (i.e., moving objects, stationary obstacles, the road lane) as well as the optimum path to follow.

Over the next two years, Visteon's AR HUD vehicle demonstrator will gain capabilities. Improved optics will allow significant increases in the field of view and the size of the image, expanding the scope of driving-environment information, Nebout said.

"Visteon is also developing artificial intelligence technologies," he added, "that will allow more natural and efficient HMI and will optimize the image positioning in accordance with the dynamics of the vehicle."

AR HUD systems also have been in development at Visteon competitor **Continental AG** since 2014.

Kami Buchholz

AEROSPACE PROPULSION

Aurora Flight Sciences partners with Uber in contested airspace

Uber announced in late April a partnership with **Aurora Flight Sciences** to develop electric vertical takeoff and landing (eVTOL) aircraft for its Uber Elevate Network. Aurora's eVTOL concept is derived from its existing XV-24A LightningStrike VTOL X-Plane subscale vehicle demonstrator (SVD) aircraft for the **U.S. Department of Defense** and from other autonomous aircraft the company has developed over the years.

Aurora has adapted and combined the autonomous flight guidance system from its Centaur optionally piloted aircraft, the lidar-based perception and collision avoidance system from the AACUS program, and the battery electric propulsion system from the XV-24A SVD to create the innovative eVTOL design.

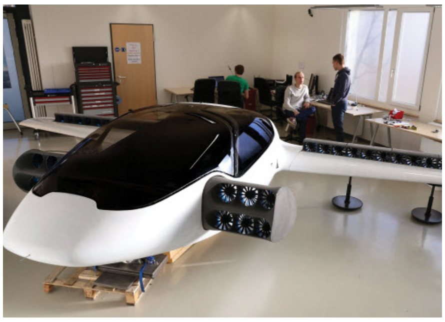
"Uber is taking a big step forward toward making the world's first VTOL network a reality and our partnership with Aurora Flight Sciences will help get us off the ground," said Mark Moore, Director of Engineering for Uber. "The Elevate VTOL network will help improve urban mobility around the world and transform the way we travel."

The partnership agreement provides the basis for a system of urban transportation solutions that will enable users of the Uber Elevate Network to request an Aurora eVTOL aircraft via Uber's computer or mobile software applications. The first successful test flight of a subscale demonstrator eVTOL vehicle occurred on April 20, 2017. Aurora's current goal will be delivering 50 full-scale aircraft for testing by 2020.

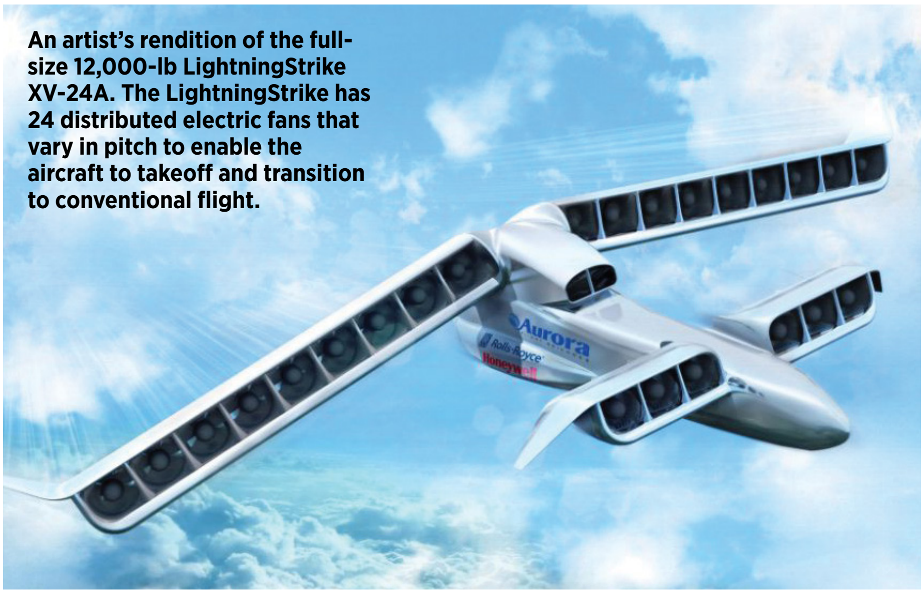
This announcement came shortly after the April 4, 2017 announcement that the XV-24A SVD successfully completed its test flight program. The 325-lb XV-24A SVD, funded by **DARPA**, demonstrated key technical features of the full-scale 12,000-lb LightningStrike XV-24A, including outbound and inbound transition flight. The XV-24A flight test program is currently scheduled to begin in late 2018.

The XV-24A, which is expected to perform manned or unmanned operations, utilizes a tilt-wing system powered by an electric distributed propulsion (EDP) system. Twenty four variable-pitch ducted fans driven by electric motors provide thrust for both hover and cruise and are designed to achieve a top sustained flight speed between 300 and 400 knots. A single **Rolls-Royce** AE 1107C turboshaft engine—used on the V-22 Osprey—drives three **Honeywell** generators that provide power to the wing and canard electric motors. Aurora aims for the XV-24A to have a 15% increase in hover efficiency and a two-fold increase in speed over modern helicopters.

The Uber and Aurora Flight Sciences eVTOL subscale demonstrator in flight. Aurora has adapted and combined technologies of its previous projects to develop the eVTOL concept.



Lilium's Lilium Jet two-seat prototype. The company announced that it had completed successful flight tests on April 20, 2017. The Lilium Jet also utilizes a variable-pitch, electric-distributed propulsion system with 36 fans.



An artist's rendition of the full-size 12,000-lb LightningStrike XV-24A. The LightningStrike has 24 distributed electric fans that vary in pitch to enable the aircraft to takeoff and transition to conventional flight.

"The Uber Elevate mission is all about low noise, high reliability and low cost," said Aurora CEO John Langford.

The XV-24A's EDP system is similar to another eVTOL craft in development—**Lilium**'s two-seater Lilium Jet prototype, which also announced successful flight tests on April 20, 2017. Similarly, Lilium is aiming to capture the market for small VTOL craft on-demand ridesharing.

The Lilium Jet zero-emissions EDP system is mounted to 12 vectoring flaps on stationary wings. It operates much the same as Aurora's XV-24A and XV-24A SVD, where downward-pointing engines lift the aircraft and then transition to a horizontal position for conventional flight. The Lilium Jet design is based on redundancy and maintainability, with 36 individually shielded engines sharing identical components. Lilium claims the aircraft is capable of approximately 160 knots with a range of 300 km.

Lilium currently is developing the Lilium Eagle, a larger, five-seat eVTOL craft designed specifically for on-demand air taxi and ride-sharing services.

William Kucinski

AUTOMOTIVE CHASSIS

Jeep's new road-efficient mud machine built in India

Just another day in the Texas boonies with Jeep engineers and the new 2017 Compass Trailhawk.

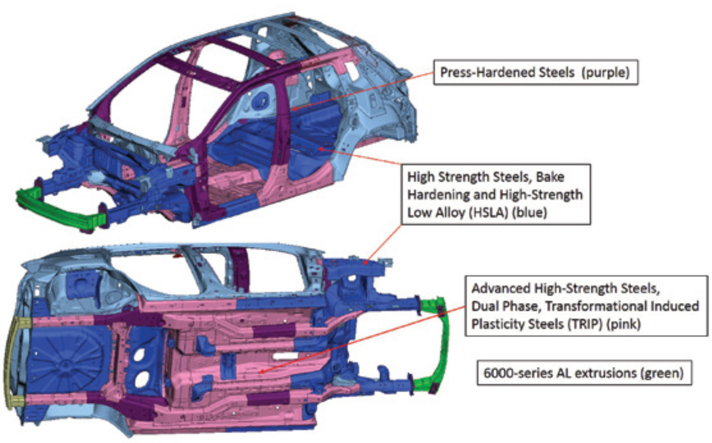
The C-segment Compass's exterior form is inspired by the Jeep Grand Cherokee (image: Ron Sessions).

Replacing the decade-old **Jeep** Compass is the new-for-2017 Compass, **FCA**'s (and Jeep's) first truly global vehicle program. Styled to resemble a slightly scaled-down Grand Cherokee, the new C-segment SUV is being produced in four plants (Mexico, China, India and Brazil) and offered in 17 powertrain combinations that include diesels and 6-speed manual gearboxes. The U.S. gets the manual 'box but not the diesel.

The new Compass is based on a stretched version of FCA's so-called "small-wide 4×4" vehicle architecture that also underpins the smaller Jeep Renegade. That platform is designed primarily as front-wheel-drive and accommodates nicely the axle-disconnect all-wheel-drive system supplied by **GKN** (see sidebar). As a "4.4-meter" car designed to fit European and other global parking spaces, the Jeep's overall length is 173 in (4394 mm), riding on a 103.8 in (2636 mm) wheelbase.

Power for U.S. models is the 2.4-L Multiair four also used in Renegade that's SAE rated at 180 hp (134 kW) and 175 lb·ft (237 N·m). Front-drive variants offer either the 6-speed manual transmission or optional 6-speed automatic transaxle that's sourced from **Hyundai**; 4×4 models get the **ZF**-designed 9-speed automatic.

There are four trim levels: Sport, Latitude, Limited, and the off-road-focused Trailhawk. *Mobility Engineering* spent a day on Texas Hill Country roads in a 4x4 Latitude, the volume model. While FCA's calibrators did a fine job making the Compass's new stop-start system unobtrusive in operation, the 9-speed is calibrated to hold its higher ratios rather than kick down and force the engine out of its fuel-consumption 'happy zone.' This creates disappointing throttle tip-in. Otherwise Compass's strut-type suspension with self-adjusting dampers gives it a nice taut feel on the road, with **Continental**-supplied electronic stability control. The chassis' dynamic experience is hampered only by slightly vague steering feel. Off-road, the Trailhawk—with 8.5 in (216 mm) of ground clearance—is a rock-crawlin' mud machine, bringing more capability here (for the roughly 10% of customers who want it) than most or all of its competitors.



Compass's body structure is composed of 65% high-strength steel alloys. The hood inner and outer are aluminum to meet global Ped Pro (pedestrian protection) impact regs. (images: FCA)

Efficient structure

The interior provides plenty of leg- and headroom for the 6-ft-3-in-tall author and overall the cabin has 27.2 ft^3 of utility with the seats deployed and 59.8 ft^3 with them folded down. A cabin highlight is FCA's latest UConnect infotainment module with larger 8.1-in screen.

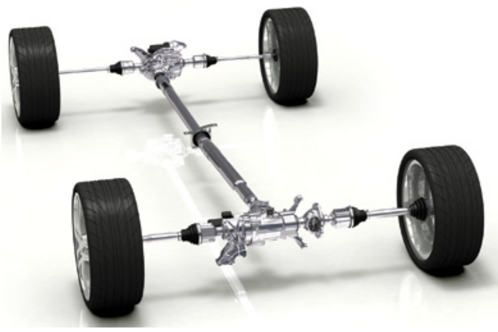
One of Jeep's main selling points for this vehicle is its fuel economy: 22 city/30 mpg highway for 9-speed 4x4 models. According to veteran FCA engineer and vehicle line exec Art Anderson, credit for those numbers goes to a combination of features, including the 'smart' AWD system that delivers refined road manners with 20:1-ratio rock-crawling capability; newly-adopted (dual battery) stop-start system that's not offered on Renegade and a mass-efficient body structure composed of 65% high-strength steel alloys (illustration at left).

The hood panels are aluminum for weight savings as well as an enabler to meet European pedestrian protection regulations.

Building a single global team

Asked about the program's biggest challenge, Anderson responded: "It's truly global! Setting up the business practices and the 'rules' to manage development, the functional objectives, the money and the 10 million customer-equivalent development miles while preparing to launch in four plants on three continents (with diesel engine supply from a fourth, Europe) was what sets Compass apart from any previous program," he noted. It is remarkable to consider that no **Fiat** program in that marque's more than 100-year history, and no Jeep in that brand's 75 years, even came close to the world-ranging scope of the 2017 Compass.

Many time zones separated the regional engineering teams. "We had a lot of 6-a.m. meetings and a lot of 6- to 10-p.m.



GKN's axle-disconnect AWD completely decouples the rear axle for greater on-road fuel economy.

The GKN rear-drive module features a side-mounted clutch.

meetings," Anderson explained. "We used Telepresence, which is a video phone call; we've had up to 7 offices from all around the globe connected on a single video discussion. And email remains reliable and effective for asking questions and getting answers across time zones."

While the Renegade program was "industrialized" across multiple regions, Compass was run as a single global team with industrializations in the four regions. Simply managing the logistics of shipping components and systems was daunting at first until FCA experts invented some new processes including "IRF", interregional flow, to move and keep track of material. "We've learned a lot about maintaining flow and keeping the supply chain running," Anderson said.

Change Control was another learning. The global team would meet on 'live' calls to discuss whether to agree to make a bill-of-material change or not. Typically these involved a specific feature request by a region; China's take rate on sunroofs is 90%, for example. "We did a good job in blending guidelines, rules and flexibility," Anderson said, echoing his praise of the entire global engineering team and FCA's suppliers in pulling it all off without a hitch. Speaking of hitches, Compass's towing capacity is rated at 2000 lb (907 kg).

Lindsay Brooke

AUTOMOTIVE MATERIALS

Lightweight door module aims to trim vehicle weight

Magna's ultralight door module, developed in collaboration with FCA, Grupo Antolin and the U.S. DoE, achieves 40%-plus mass savings versus current production counterparts.

A new ultralight door architecture nets a 42.5% weight savings compared to a current production door—and that's enough to put this lightweight concept in an enviable position.

"This lightweight door module has a great opportunity to be commercialized. It's not just high-tech. It's also at the right cost," said Reuben Sarkar, Deputy Assistant Secretary for Transportation, Energy Efficiency and Renewable Energy at the **U.S. Department of Energy**.

Sarkar and Ian Simmons, Vice President Business Development, Corporate Engineering and R&D at **Magna**, spoke with *Mobility Engineering* following a press conference detailing the lightweight door project at the recent 2017 Detroit auto show.

Magna, in cooperation with the DoE and partners **FCA** US and **Grupo Antolin**, developed the driver's-side door in less than 10 months.

Aluminum accounts for approximately half of the total mass reduction of the door-in-white assembly. The door module also includes Magna's SmartLatch electronic latch system, which eliminates the need for mechanical hardware.

Grupo Antolin's contributions in the area of molding techniques and polymers represented approximately 7% of the total mass reduction.

"This lightweight door was done with today's production materials and today's production processes and methodologies in mind. It's a holistic approach that includes the module, door inner, mirror and trim," said Simmons.

The concept door also was developed at significantly less than the venture's cost bogie. "The target in terms of cost was approximately $5 per pound and we came in at $2.59 per pound," Simmons said.

Simulation showed the door module passing all safety and durability requirements. "FCA US is supporting us with all the prototype builds and all the testing. And it's their functional requirements that we simulated," said Simmons, "All the simulation work and all the initial testing has come back positive."

Next steps include the manufacture of full-scale prototype door assemblies, performance tests and safety tests to validate the design. The goal is to have the lightweight door available for production vehicles by the fall of 2020.

Kami Buchholz

AEROSPACE ELECTRONICS

New sensor payload helps Global Hawk stay relevant

Northrop Grumman completed its successful inaugural flight test of the **UTC Aerospace Systems** (UTAS) MS-177 sensor payload on an RQ-4 Global Hawk on March 1, 2017. The flight tests mark the first time the sensor has been flown on a high-altitude, long-range autonomous aircraft. The MS-177 next-generation multispectral sensor provides the capability to "find" targets using broad area search and different sensing technologies, and to also fix, track, and assess targets through its modernized optronics and multiple sensing modalities. The MS-177 also has a field of view 20° wider than the currently equipped sensor, thanks to a gimbaled rotational mount.

"The MS-177 is the new benchmark in imaging intelligence, surveillance, and reconnaissance (ISR) sensors and its integration into the Global Hawk platform expands the mission capability we can provide," said Mick Jaggers, Vice President and Program Manager of Northrop's Global Hawk program.

MS-177 testing is expected to continue through the first half of 2017. The successful flight test at Northrop's Palmdale, CA, facility follows the demonstration of two **Lockheed Martin** U-2 sensors previously unavailable on the Global Hawk: the Senior Year Electro-Optical Reconnaissance System (SYERS-2) intelligence gathering sensor in February 2016 and recently completed flight tests of the Optical Bar Camera (OBC). Those demonstrations were conducted with an RQ-4 modified with Northrop's Universal Payload Adaptor (UPA).

While the MS-177 was first flown on a Northrop E-8C Joint Surviellance Target Attack Radar System (JSTARS) in 2011, and then on **General Atomics Aeronautical Systems**' Predator C Avenger demonstrator in 2016, the RQ-4 is slated to become the first aircraft to carry to the sensor operationally. The MS-177 will likely replace the previously tested SYERS-2 system.

"This successful flight is an aggressive effort to demonstrate Global Hawk's versatility and effectiveness in carrying a variety of sensor payloads and support establishing OMS [open mission systems] compliancy," said Jaggers. "This is going to open up an entire world for the operators of Global Hawk."

Northrop Grumman has begun flight testing of the MS-177 sensor payload with a successful inaugural flight on an RQ-4 Global Hawk high-altitude, long-endurance autonomous aircraft system.

Two Northrop Grumman MQ-4C Triton unmanned aerial vehicles on the tarmac at a Northrop Grumman test facility in Palmdale, CA.

The unmanned RQ-4 Global Hawk, now on its Block 40 iteration, has a service ceiling of 60,000 ft, can fly at high altitudes for greater than 30 hours, and has a range of approximately 14,000 mi.

It is designed to gather near-real-time, high-resolution imagery of large areas of land—up to 40,000 mi^2 per day, in all types of weather—day or night. In active operation with the **U.S. Air Force** (USAF) since 2001, Global Hawk has amassed more than 200,000 flight hours with missions flown in support of military and humanitarian operations

In 2015, the USAF planned to retire the U-2 in favor of the RQ-4 and its lower of operating costs. This would have marked the first time that an unmanned aircraft completely replaced a manned aircraft. However, due to sequestration complications, it was decided that the U-2 would continue to fly through 2018.

The RQ-4's ability to fill the role of the U-2 hinges on further developing the platform. Operating more capable sensors more reliably helps to make it a more cost-effective alternative to manned surveillance and reconnaissance aircraft. One of the major issues concerning the USAF unmanned fleet is that the RQ-4, MQ-9, and RQ-7 aircraft cannot fly through inclement weather due to a lack of in-flight de-icing equipment. However, multiple organizations are looking to refit U.S. unmanned aircraft with various de-icing measures, including **Battelle**.

Battelle's self-developed solution involves coating leading wing surfaces with a special, suspended-carbon nanotube paint layer in strategic locations. The "Heatcoat" solution possesses enhanced thermal conductivity, includes no moving parts, and is ultra-lightweight; key characteristics to consider for the unmanned platforms that are operated with zero excess power and weight.

In addition to the significant technology upgrades, the RQ-4 is now about 50% cheaper to operate, costing about $14,500 per flight hour compared to the U-2's $32,000. "What we're trying to do on Global Hawk is make it the preferred high-altitude ISR system," said Jaggers.

William Kucinski

TRUCK POWERTRAIN

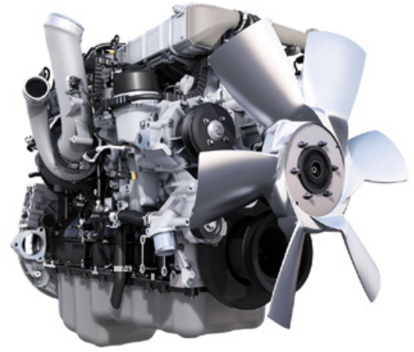
International develops new, lighter A26 engine to replace N13

Any time a new engine is announced, it is major news. Pairing a new engine with a new approach to engine development is even bigger news. **International Truck** recently unveiled its all-new engine for the Class 8 market: the International A26. Along with that came news of an initiative called Project Alpha, which brought together a small team of powertrain engineers dedicated to a new perspective on engine development.

"The A26 was designed from the ground up to deliver industry-leading uptime, durability and reliability," said Darren Gosbee, vice president of advanced engineering. The 12.4-L A26 sources a **MAN** D26 inline 6-cylinder crankcase from their partnership with the **Volkswagen** Group and surrounds it with numerous all-new components to optimize four key criteria: uptime, fuel efficiency, weight and NVH (noise, vibration and harshness).

The engine weighs only 2299 lb (1043 kg), which is 55 lb (25 kg) less than the **Navistar** N13 engine it replaces and 600-700 lb (272-318 kg) lighter than traditional 15-L big bore engines. Despite the reduction in weight, the engine can still produce up to 475 hp (354 kW) and 1750 lb·ft (2373 N·m).

Simplicity was one of the focal points of the engine design to deliver maximum uptime. "The A26 is as simple as a modern engine can be, and we've built uptime into every part of the development process, from design to calibration to testing," said Gosbee. Larger piston pins, connecting rods and bushings are used for better load distribution. Smaller piston cooling jets have increased oil pressure and help extend oil change service intervals up to 70,000 mi (112,654 km).



A six-blade fan was chosen over the previous eleven-blade, which allows for quieter operation in addition to reducing power consumption.

Other improvements across engine systems have helped deliver up to a 5% increase in fuel economy. The new **BorgWarner** single-stage variable-geometry turbocharger (VGT) leads off a simplified air management system. The **Bosch** 2500-bar (36,259-psi) high pressure common rail fuel system and new cylinder head with coolant passages that are 50% less restrictive help reduce both fuel consumption and emissions.

Simplification also helped lead to keeping the International A26 lightweight, in addition to component material choices. A titanium compressor wheel was used instead of aluminum for improved fatigue life while continuing to reduce weight. Composite valve covers and an aluminum flywheel housing provided additional weight savings.

To improve NVH, the A26 has a new sculpted crankcase with an isolated oil pan and rubber gasket designed to absorb vibrations. A six-blade fan was specified over the previous eleven-blade, which allows for quieter operation in addition to reducing power consumption. The engine calibration also is programmed for reduced engine noise.

Jacobs Vehicle Systems collaborated with Navistar engineers to provide a factory-installed compression-release engine brake for the A26 engine. "By leveraging the benefits of the new variable-geometry turbo, the A26 engine brake performance increased up to 67% at lower engine speeds and higher altitudes," according to Jacobs. Other stated benefits include a reduction in the need for downshifting and improved NVH.

Project Alpha initiative speeds development

All of these improvements were the goal of Project Alpha, a brand-new initiative by International for this engine's development. "Project Alpha has fundamentally changed how we design diesel engines," says Bill Kozek, president of Truck and Parts. The group was formed using fewer members to speed up and focus engine design decisions. They were also given more autonomy in their decision making to not only meet the 2017 emissions regulations but improve the overall product performance in those four key areas.

Many of the reciprocating components like the connecting rods, piston pins and pistons were replaced to increase the compression ratio up to 18.5:1.

One of the mandates Project Alpha decided on was to leverage proven industry technologies over testing new ones on customers. "Keep the best and improve the rest," was a mantra for Jim Nachtman, marketing manager of Heavy-Duty Product Line. The crankshaft, main and rod bearings, EGR cooler and valves, oil and fuel filters, air compressors and flywheel housing along with several other components were carried over from the Navistar N13 engine. However, many of the reciprocating components like the connecting rods, piston pins and pistons were replaced to increase the compression ratio up to 18.5:1. A slower, single-speed water pump was chosen over a variable speed pump to improve the fuel economy and reduce complexity.

The Project Alpha team put the A26 engine through hundreds of thousands of hours of dynamometer testing at severe engine speeds and loads. "It's been tested to extremes and meets a demanding B10 design life standard for an unprecedented 1.2 million miles," said Kozek. The engine was temperature tested as low as -40°F (-40°C), which was aided by a switch to Compact Graphite Iron (CGI) for the crankcase; CGI has better thermal fatigue than traditional gray iron.

The A26 now will be available in the International LT Series trucks. International is backing the engine with a two-year, unlimited mile warranty. It is the first of a new wave of engines for International trucks. The Project Alpha team and A26 engine are a new beginning for the brand.

Matthew Borst

AUTOMOTIVE ELECTRONICS

Haptic feedback for gesture-control HMI

BMW has gesture control in production on its 7 and 5 Series cars. At CES17 the company unveiled a concept called HoloActive Touch (shown) which combines gesture control, head-up display and direct touchscreen operation (image: BMW).

Gesture control is becoming more commonplace in many of the devices we use in our daily lives, from games consoles, swiping and pinching on mobile phones, to point-of-sale devices such as ticketing systems in train stations. The automotive segment is already adopting gesture control for infotainment systems as well as serving as a human-machine interface (HMI) for subsystems such as the sunroof, climate control and audio.

BMW's latest 7-Series and 5-Series offer an HMI system that can detect four different gestures: setting the car's navigation, browsing apps and starting the audio, answering phone calls and controlling the on-board computer. **Volkswagen** last year announced gesture controls on its Golf and pledges to spread the technology across its model ranges. Other major OEMs have the technology in their product pipelines.

Early reviews of gesture controls from the road-test media have been a mixed bag. While the reviewers have been impressed with the technology, they've not been thoroughly pleased with the functionality. In the 7-Series, for example, the driver can change the audio volume via a hand-circle motion, answer or dismiss a phone call using a left and right swiping motion, and use a two-fingers-down swipe to affect a user-configurable setting.

For designers and engineers developing and integrating new HMI, one of the challenges is providing the driver with the ability to manipulate gesture-controlled equipment while driving, without taking his or her eyes off the road. The logical solution is in using virtual controls combined with mid-air haptic feedback. Future systems from **Ultrahaptics** could offer designs that are infinitely more flexible.

The missing link

How can gesture-controlled interfaces integrate with the automobile infotainment/comfort control system in both safe and simple ways which the driver can trust? Current forms of touchless gesture control fall short of the requirements for effective human-machine communication: Feedback.

Voice-controlled systems can be difficult to operate; often exact phases require memorization and long menu chains must be navigated to obtain the desired effect. Voice can have such a variation from one user to another that the recognition software can make mistakes when 'listening;' the result can be a very frustrated driver that defaults back to traditional controls.

Touch is a modern form of control and works to a point. The disadvantage is that drivers can lose sight of the road for precious seconds while manipulating the infotainment or comfort system controls. Again, it is often difficult to navigate multiple nested menus and options while driving safely.

Tried and true physical controls are becoming increasingly sophisticated with multi-function switches, navigation knobs and selection buttons. There is a lot of wiring and hardware for designers and engineers to consider here, not to mention packaging/real estate and placement.

Gesture control has become a simple and familiar approach to system control and is used quite well in many industries. Mid-air gesture control, most commonplace in gaming systems and virtual reality, is well suited for the automotive environment. While driving, the driver can maintain vigilance while manipulating vehicle amenities; one would seldom need to glance away from the road. The failure of mid-air gesture control lies in feedback to the user. The driver may never know where the controls are or whether the control was confirmed and executed. But that is about to change thanks to new developments.

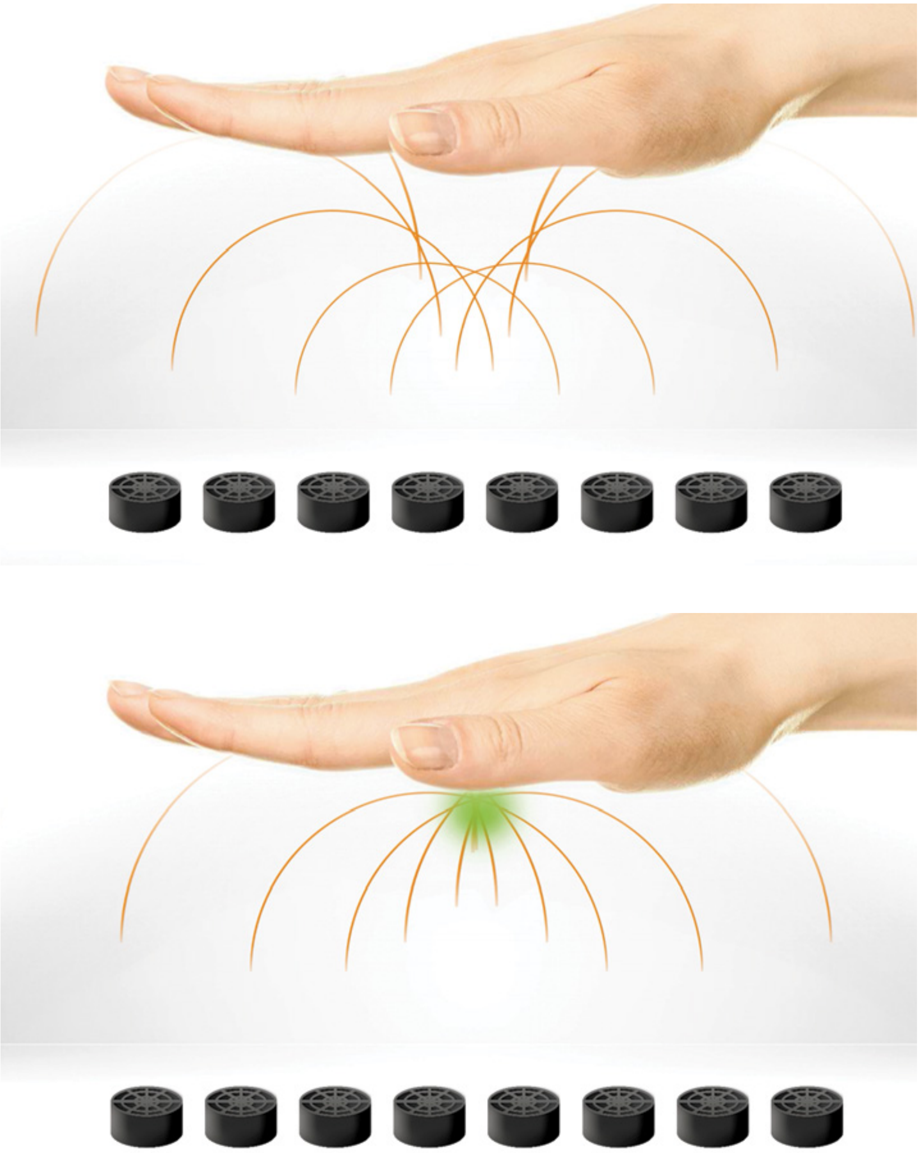
Leap Motion Sensing is the key

Ultrahaptics' mid-air haptic technology is currently unique in the industry. The haptic system allows a user to feel and manipulate virtual objects in mid-air as if they were touching real physical controls.

Currently, the system's motion tracking ability is mainly based on the Leap Motion sensor, which tracks your hand in free space. The tactile interface is generated by an array of ultrasonic transducers, similar to those used in the reverse-warning systems in most modern cars.

The transducers generate ultrasonic waves at 40 kHz that cause constructive interference where the waves meet. These interference points can be manipulated to create invisible turbulence points that you can feel. The secret is, to control the touch sensation, sophisticated computer algorithms are implemented to manage this

Having haptic feedback and touchless gesture control at a variety of vehicle HMI points enables the driver to keep eyes on the road.



Ultrahaptics technology uses ultrasound transducers to create focal points which generate haptic feedback on the skin.

distortion by modulating the ultrasound beams.

Using a 16 x 16 array, haptic sensations can be produced up to 1 m (3.2 ft) away, with a focal point accuracy of 8.6-mm (.33-in) diameter—within a finger's width.

The result of this modulation is that the user feels pressure where the beams focus on the hand. For example, a close-focused beam could simulate the sensation of a curved knob or button and a rapid modulation pattern would feel much like rubbing over a corrugated surface.

'Touchless infotainment/HMI'

In the case of automotive infotainment systems, progression toward gesture-based controls seems to be the natural industry evolution. Most consumers are already familiar with the control method. Mid-air gestures are well suited for the automotive environment. What might such gesture control look like?

One implementation might be to create an interaction zone somewhere central to the dashboard (in a traditional placement). If the driver passes their hand through an acoustic barrier, they could actively feel where the boundaries of the interaction zone are. They would then know they can make appropriate gestures to control the infotainment system.

Another method might look for the driver's hand. Imagine that the driver places their hand within an interaction zone, then using the systems cameras and image processing ability, a virtual control could be locked to the hand.

While activating the ultrasonic transducers with a predefined gesture a virtual button or knob could be continually available to the driver, even if their hand moves around within the interaction zone.

With these new design concepts, HMI related to drive control of the HVAC, power windows, sunroof, seat adjustments, and other systems, could be easily integrated into the infotainment center creating a new kind of all-inclusive control nexus within the cockpit.

Development of integrated, stylish and easy to use infotainment and comfort control systems are now only limited by the designer's imagination. Displays could be set up in a conventional way, with a primary central screen that contains all the visual feedback the driver needs. This would effectively leave controls as familiar to drivers as they have been for years.

Alternatively, automotive interior designers could explore new approaches to in-car infotainment. With new curved screen technologies, display information could integrate into the dash almost anywhere, in almost any shape. The ultrasonic sensor array could be placed appropriately to allow for effective mid-air feedback, creating an innovative, modern interior design.

A designer could also could explore new technologies. Head-up display options may be viable, or laser-display projectors within the windshield. All are plausible options due to mid-air gesture control and feedback. The result: nearly endless design possibilities.

Smart Design

The technology that Ultrahaptics has introduced may well transform the way in which vehicle drivers control the technology at their disposal. New users bringing their experience with gestures from other tech gadgets will help minimize learning curves and make systems more intuitive to use. Line-of-site would be less used, leaving the driver's eyes trained on the road rather than on in-car distractions. And under the 'skin,' control systems can be less complex regarding wiring, mechanical mechanisms and the bill of material. ■

David Owen is VP—Business Development at Ultrahaptics. A graduate engineer, he has held senior management roles with Philips, GEC Plessey and Ferranti.

TRUCK ELECTRIFICATION

Hyliion develops add-on hybrid system for semi-trailers that reduces fuel consumption by 30%

Hyliion has developed an add-on hybrid system for tractor-trailers that will reduce fuel consumption by about 30% with a return on investment of less than one year, according to Thomas Healy, CEO and founder of the Pittsburgh, PA-based startup.

"What makes our system unique is that we solely focus on the trailer," Healy said to *Mobility Engineering*. "We replace the existing rear axle assembly under the trailer with an electric propulsion system. So now what happens is when the vehicle is slowing down or going downhill, we're able to capture all that wasted energy and store it in the battery pack on the trailer."

When the truck accelerates or starts an uphill stretch, the system drives the rear tires on the trailer. "So the diesel engine in the truck doesn't have to work as hard, there's not as much load it needs to pull," he said.

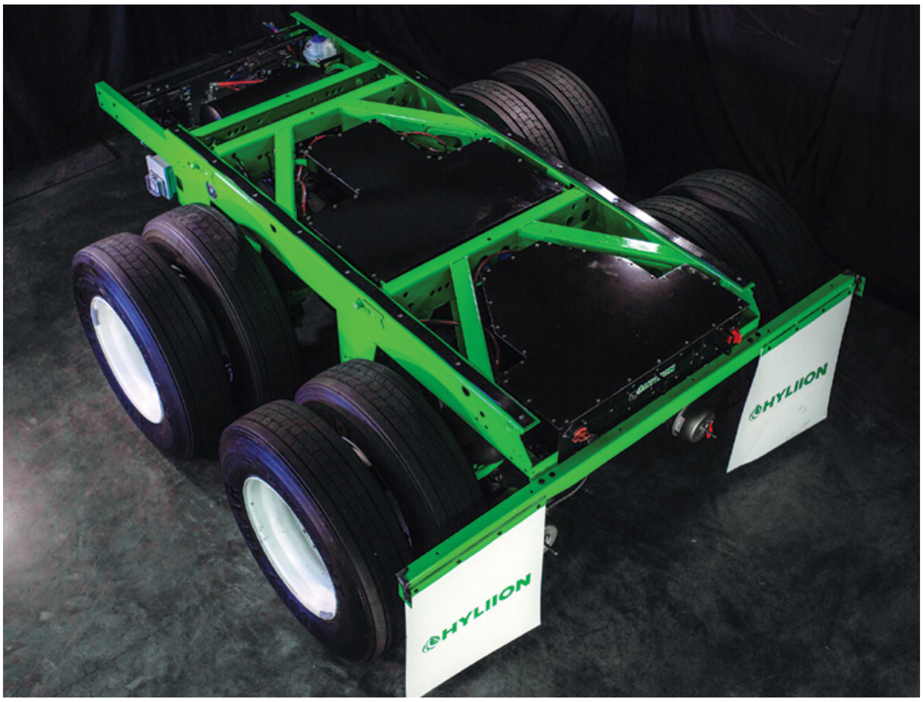
The intelligent electric drive axle system was recently awarded the grand prize in the 2016 "Create the Future" Design Contest produced by **Tech Briefs Media Group**, beating out more than 1100 product ideas from 71 countries. The contest was co-sponsored by **COMSOL** and **Mouser Electronics**, with **Analog Devices** and **Intel** serving as supporting sponsors.

(Additional category winners in Aerospace & Defense, Automotive, Electronics and more can be viewed at www.createthefuturecontest.com.)

Most conventional hybrid strategies integrate an electric motor into the drivetrain of the truck. "Since we don't

Going uphill, the electric drive axle system applies positive torque to the rear wheels on the trailer, so the diesel engine in the truck doesn't have to work as hard.

When the vehicle is going downhill, the system captures wasted energy and stores it in the battery pack on the trailer.



Hyliion's electric-drive system hybridizes the trailer portion of the tractor-trailer combination and uses regenerative braking to capture power, possibly saving the trucking industry billions in fuel costs.

integrate right into the drivetrain, you can keep all that existing equipment and not make any modifications to it. We're getting the benefits of a hybrid system but with an add-on solution," Healy said.

Essentially, Hyliion is turning a passive axle into a drive axle. "It's like taking one of the axles off the truck and putting it on the trailer," he explained. "So now we have a drive axle that we can apply positive and negative torque, with an electric motor connected to the axle." The electric motor is connected to a control system with a lithium-based battery pack.

The company leverages existing components to help bring the product to market faster. For example, the axle is a production component that's already been tested and has the weight rating certifications needed to travel over the road.

The system can be installed on nearly every trailer type in less than one hour, the company claims, without changing trailer height or length.

The electric drive axle system is categorized as an auxiliary power unit (APU), capable of powering auxiliaries overnight such as electronics and air-conditioning. Even though the system adds about 500 lb (227 kg) to a tractor-trailer, "the government in most states allows you to carry anywhere from 400-450 extra pounds of payload if you're running an APU. So it's really not netting much of a loss of cargo that you can carry," Healy said.

The electric drive axle doesn't have any data communication with the truck. The system's sensors are able to determine when to apply power and when to capture energy. It does have cellular communication and satellite, so the vehicle can be tracked.

"From a fleet standpoint, you can look at how fast your trailers are moving and where they're located, and we can do things like tell you how much load is in the trailer," Healy said.

Information is available to the driver via a mobile dashboard application. The driver also has the ability to turn the system on and off.

Final Phase 2 greenhouse gas standards, affecting model year 2021-2027 medium- and heavy-duty on-highway vehicles, mandate for the first time that fuel-saving technology be employed on the trailer in addition to the truck. (See pages 6 and 32 for more on Phase 2 regulations.)

"Our single product is able to propel you above those mandated requirements," said Healy. "We see it being a

"We see [this system] as a perfect solution for this new Phase 2 mandate that's coming out. From a timing standpoint, it couldn't be better," said Hyliion CEO and founder Thomas Healy.

perfect solution for this new Phase 2 mandate that's coming out. From a timing standpoint, it couldn't be better."

Hyliion currently has six trucks running with its system for internal testing and validation. "The next phase is we've got over 30 fleets that have signed into our pilot program that we're going to start delivering units to before the end of this year," he said.

In-house production of the electric drive axle system is expected to begin Q1 2017, and the company is lining up outsourced production for higher volumes in Q2 2017.

"Our next big milestone is really setting up the production," Healy shared. "There is a lot of demand in the industry for a product like this...How can we manage all the production and supply chain so that we can grow at a very fast pace and get our partners alongside us to grow at the same rate? Our mindset is scaling up production as fast as possible to as high a volume as possible."

Ryan Gehm

Alternative fuels and challenges

As of today, most transport vehicles use petroleum-based fuels. Although there are alternative-fueled technology demonstrators such as the Mahindra E_2O or Tesla battery-electric models currently available, it will take time for these alternatives to compete with petroleum-based fuels and achieve commercial acceptance.

A selection of various transport vehicles and the fuels typically used to power them:

- Cars and motorcycles/scooters: gasoline, diesel, CNG, LPG, battery-electric
- Commercial trucks: diesel
- Buses: diesel, CNG, battery-electric
- Rail: electricity, diesel, coal
- Small aircraft with reciprocating-engines: gasoline or Avgas
- Larger aircraft with turbine engines: jet fuel or kerosene

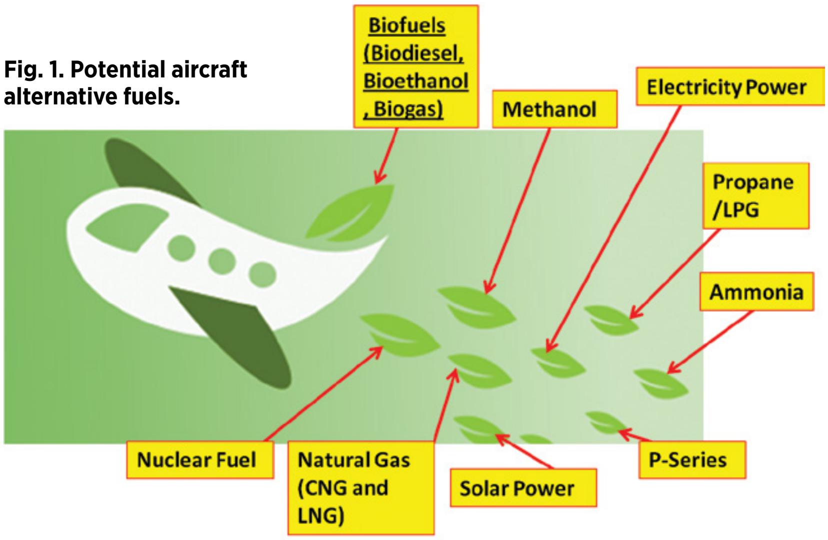
There are several considerations that motivate us to seek alternative fuels; among them are depletion of resources, technical advances and environmental concerns.

Due to these considerations, engineers and researchers continue to develop alternative fuels. Most of the methods required to use alternative fuels are technologically possible and have been demonstrated in labs or on prototype vehicles. It may take many years for these alternatives to become economically feasible and until they become economically viable, technologists will work to improve their market acceptance.

In this article, we discuss how alternative fuels could be used in aircraft. Some of the potential options:

Fig. 2. Solar One: 11,628 solar cells, four 100-kg lithium-ion batteries, goal of 36 hours of continuous flight.

Fig. 1. Potential aircraft alternative fuels.



Solar power

Using this technology, an aircraft named Solar One uses electricity generated by solar panels. The conversion of solar power from sun into electricity through the photovoltaic array converts solar energy to direct current (DC) electricity and an inverter converts the DC output to alternating current (AC) electricity. Advantages include: it is renewable energy, there is no waste and solar needs little required maintenance. It also has disadvantages: solar cannot produce electricity at night and the panels are expensive.

Battery-electric power

In place of internal-combustion engines, the aircraft is propelled by electric motors powered by electricity coming from batteries. Most electric vehicles use lithium-ion batteries because of higher energy density, a longer lifespan and higher power density than other battery chemistries.

Electric-powered aircraft could be extremely environment friendly, as there will be less vibration, no odor and less noise, all of which generally are associated with fossil fuels. At present there remain many challenges, such as increased weight, high cost and battery reliability. Due to these limitations, a battery-electric aircraft cannot cover long distance in one flight.

The X -57 **Maxwell** aircraft's two gasoline-fueled piston engines are replaced with a long, skinny wing embedded with 14 electric motors—12 on the leading edge for take offs and landings, and one larger motor on each wing tip for use at cruise altitude.

Nuclear fuel

Nuclear fuel typically is used in stationary powerplants to produce heat that powers electricity-generating turbines. Most nuclear fuels contain heavy fissile elements to enable nuclear fission, such as uranium-235 or plutonium-239. The concept has the advantages of less fuel payload (considerable energy is available from a small amount of uranium) and there are no greenhouse-gas emissions.

The risks associated with storing and disposing of nuclear fuels remain a huge challenge.

Fig 3. Maxwell battery-electric aircraft.

Fig 4. Biofuel (biodiesel, bioethanol, biogas)-powered aircraft such as the Boeing ecoDemonstrator have reasonable potential.

Fig 5. Boeing LNG-fueled SUGAR Freeze.

Fig 6. Tupolev Tu-155, also fueled by LNG.

Biofuels (Biodiesel, Bioethanol, Biogas)

Biofuels have potential to entirely replace conventional diesel and gasoline. Biofuel sources include plant materials, certain types of crops like jathropa and recycled or waste vegetable oils (any refined vegetable oil obtained from cooking sources).

A demonstration **Boeing** 757 test flight in 2011 experimented with the blend of 15% "green" diesel and 85% petroleum-based jet fuel in the left engine. Green diesel typically is comprised of vegetable oils, waste cooking oil and waste animal fats.

The Boeing demonstration projects a reduction in environmental impact through the airplane's lifecycle, from improving fuel efficiency and cutting carbon emissions to recycling production materials. It also has disadvantages, however: the fuel is not suitable for use in low temperature; it can lead to higher incidence of fuel-system clogging and its source material requires increased use of fertilizers.

Biofuels can be used in any compression-ignition engine that will accept conventional diesel fuel. Currently, India meets its energy needs mostly by importing fossil fuels, but with biofuels the country could meet its needs with internally-produced fuel. There has been mixing of ethanol in fuel in India and Brazil.

The Indian government is investing in collaboration with Canada to conduct research on "second-generation" biofuels such as ethanol from cellulosic feedstock and biomass-to-liquid fuels to power flexible-fuel aircraft engines.

Natural Gas

Natural gas is an alternative fuel that burns cleanly and is easily available in many countries through utilities that provide natural gas to homes and businesses. Compressed natural gas, or CNG, is mainly composed of methane and can be used instead of gasoline or diesel to fuel conventional combustion engines. Combustion of methane produces the least amount of CO_2 of all fossil fuels and CNG typically is cheaper than most other fuels. Due to absence of lead, fouling of spark plugs is eliminated. The primary CNG disadvantage is that it requires large and heavy pressure tanks for storage, so it generally is ruled out for aircraft fuel.

Another option is liquefied natural gas (LNG), natural gas (predominantly methane, with some mixture of ethane) in liquid form for ease of storage and transport; LNG is produced when natural gas is cooled to minus 259 deg through the process known as liquefaction.

The **Tupolev** Tu-155 and the Boeing SUGAR Freeze aircraft (made by Boeing's Subsonic Ultra Green Aircraft Research, or "SUGAR" team) developed under **NASA**'s N+4 Advanced Concept Development program were designed to run on LNG.

It is a more economical source of energy when compared to fossil fuels and LPG; the primary LNG disadvantages are the high cost of cryogenic storage onboard vehicles and the major infrastructure requirement of LNG dispensing stations.

Methanol

Methanol is another alternative fuel for internal-combustion and other engines, used either directly or in combination with gasoline. Methanol can be used as an alternative fuel in flexible-fuel vehicles designed to run on M85, a blend of 85% methanol and 15% gasoline.

Fig 7. Propane-powered aircraft: Bombardier CRJ-1000 'EC-LPG during a test flight at Bologna Guglielmo Marconi Airport, April 2013.

Methanol has the potential to provide a bridge to the hydrogen economy of the future. Methanol can be used to generate hydrogen and the methanol industry is working on technologies that would allow methanol to produce hydrogen for fuel cells. There are significant health and environmental benefits with the use of M85 and it can be dispensed from pumps much the same as gasoline. Methanol also can be created cheaply with no carbon release.

However methanol is more corrosive than petroleum-based liquid fuels, making it difficult to use with standard engine parts. Methanol fuel also contains less energy, so offers less mileage per gallon. Methanol is a toxic substance and can be harmful if swallowed, absorbed through the skin, or inhaled, impacting its safety. A methanol engine also can cause cold-start problems in cold weather or vapor lock in hot conditions.

Propane

Propane—also called liquefied petroleum gas or LPG—is a byproduct of natural-gas processing and crude oil refining. Widely used as a fuel for cooking and heating, propane also is a popular alternative fuel for vehicles.

Propane combustion adds fewer toxins to the air than other fuels and is less flammable. Refuelling a propane vehicle is similar to filling the tank for a cooking grill; the time required for refueling is comparable with that needed to fill a CNG, gasoline or diesel fuel tank. Propane's high octane rating enables it to mix better with air and to burn more completely than does gasoline, generating less carbon.

The main disadvantage of LPG is with the storage and safety. Storing LPG requires sturdy tanks and cylinders and transporting LPG is not easy. The fuel itself is highly inflammable, thus potentially very hazardous. It also can damage engine valves. LPG is more expensive than CNG or gasoline.

P-Series

P-Series is a relatively new alternative fuel: it is a mix of natural-gas liquids, ethanol and biomass extracts. It has low emissions in comparison to gasoline; the greenhouse-gas emissions are about half that of gasoline.

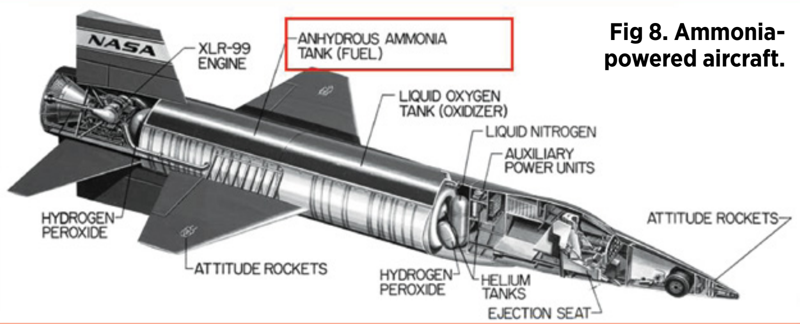


Fig 8. Ammonia-powered aircraft.

The use of P-Series can reduce fossil-fuel energy use by almost half, as well as significantly cut use of petroleum fuels. P-Series comes almost completely from domestic renewable sources and major companies such as **FCA** and **Ford** have begun making models that support P-Series as an alternative fuel.

After acceptance in automobiles, this new fuel also could be used for aircraft. P-Series fuel has the advantage that it can be used alone or mixed with gasoline in any ratio by simply adding it to the tank. It will lead to reductions in hydrocarbon and carbon monoxide emissions, toxics and greenhouse gases, although mileage for vehicles using P-Series fuels has been demonstrated to be about 10% less per gallon than gasoline.

Ammonia

Ammonia has been proposed as a practical alternative to fossil fuel for internal-combustion engines. Ammonia is sometimes called the "other hydrogen" due to its structure of three hydrogen molecules and one nitrogen molecule. Figure 8 is an image of the liquid-ammonia fueled **Reaction Motors** XLR99 rocket engine that powered the X-15 hypersonic research aircraft.

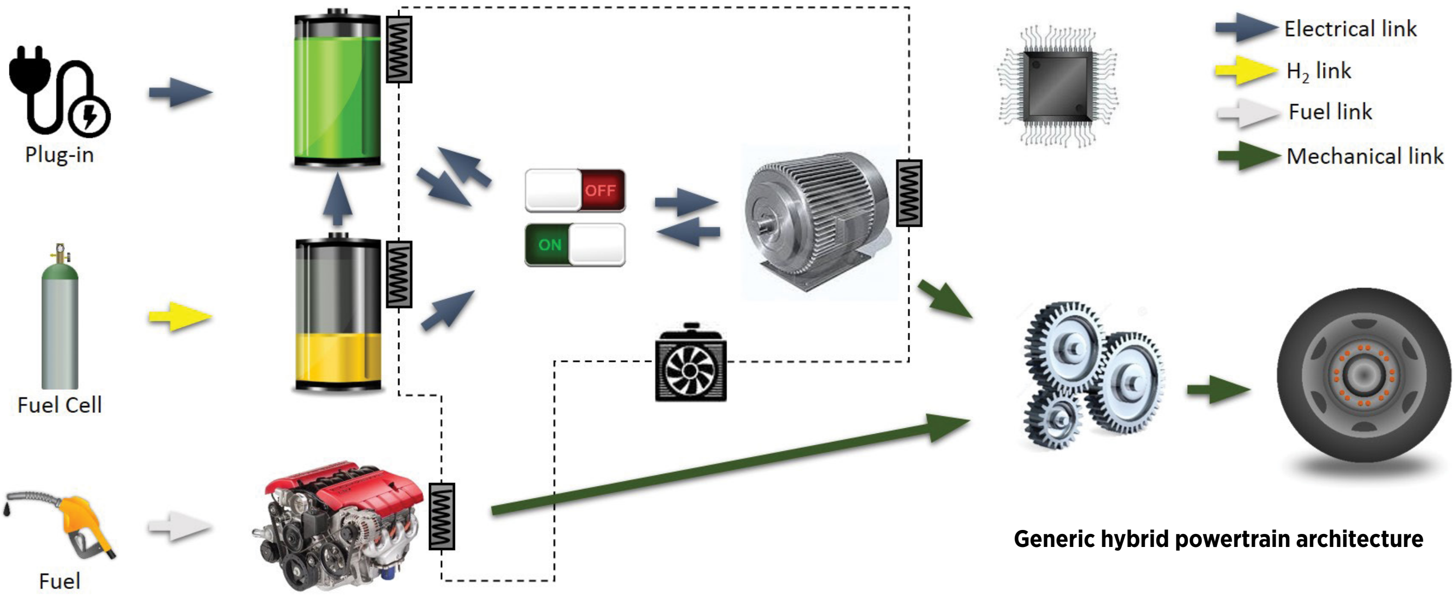
Ammonia has many advantages: it left no deposit in the reusable rocket engine and its density is almost equal to the density of the oxidizer, liquid oxygen, which simplified the aircraft's design. Ammonia as a fuel also has the benefit of being carbon-free and can be handled in the existing infrastructure.

Conclusion

Scientists and technologists are continually working towards developing alternatives for fossil fuels. On one hand, there are some alternatives available today, but using them is expensive. On the other hand, some alternative fuels are all but impossible to use today—but could become future reality. We can confidently say that due to technology advances, alternative fuels will be developed well before the world runs out of fossil fuels. This will lead the way for reduction in greenhouse gases and a cleaner and safer environment for future generations.

Authors: Sachin Vishnoi is principal engineer at UTC Aerospace Systems in Bengaluru and has approximately 20 years of experience in the aircraft industry in various organizations such as UTC, NAL, Capgemini, QuEST Global and Mesco Airlines. Nitin Dixit is an engineer at UTC Aerospace Systems, Bengaluru and has six years of experience in the aircraft industry in organizations such as UTC, Canadian Aerospace Electronics (CAE) and Border Security Force (BSF).

Automotive powertrain development: virtually-connected hardware co-simulation



Generic hybrid powertrain architecture

The automotive industry is capital-intensive—and it is not just hefty manufacturing investments that make it that way: product development also is a major sink for industry capital. Development of a new vehicle from a clean sheet may take up to five years, which escalates R&D investments as high as 10% of revenue for small to medium manufacturers.

Because of these long-term deep investments, the industry generally has been reluctant to invest in hasty change.

But the ongoing global emphasis on environmental regulations has forced the automotive industry to more rapidly and disruptively intensify its development focus on electrified powertrains, burning an even larger hole in R&D budgets. Moreover, the influx of Silicon Valley corporations—with their virtually bottomless pockets and comparatively small manufacturing spends—has put the contemporary auto giants in a tough spot.

The consequences of these trends have been far-reaching within the industry framework. First, most OEMs are completely restructuring their supply chain; second, product development is becoming more virtual and dynamic than historical trends would predict.

This second aspect of these product-development trends—the increase in virtual-development activity—is the focus of this analysis.

'Hybrid' development techniques: promising potential

Traditionally, a real (i.e. physical) prototype of a vehicle is introduced at moderately early stages in the development cycle, around midway of completion. Although that means highly-accurate testing results can be obtained, several iterations and modifications are typically needed at such an early stage of development—demanding multiple prototype builds and escalating costs. If there are accurate virtual (or a hybrid of real and virtual) modeling strategies at hand, real prototyping can be pushed back further, drastically reducing time and money spent.

Modeling and simulation using a "hybrid" approach is proving to be more promising than real prototyping, particularly in light of expanding computing capability and nearly-continual organizational cost-reduction pressures. Hardware-in-the-loop (HiL) simulation is a well-evolved and popular strategy to address these needs by exploiting the best of both product-development worlds: real hardware with behavior not accurately reproducible by models is interfaced in a system-simulation loop without significantly adding to the cost equation as would testing a series of real prototypes.

Another important prospect for virtual development is remote co-simulation. How good would it be if a cross-geographic system simulation model was possible where the different R&D facilities could patch their hardware to the "loop" and simulate in a decentralized fashion?

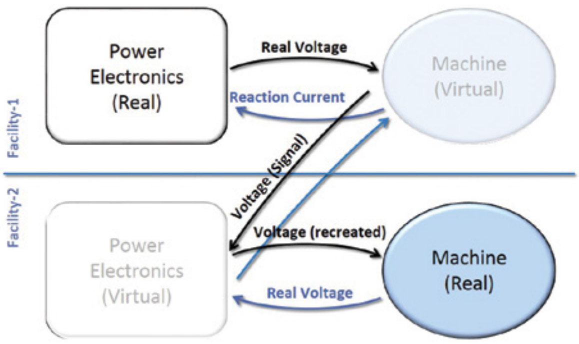
Today, considerable development resources are spent on the logistics to physically bring together different components of a hybrid powertrain—motors, batteries, the IC engine, to name a few—to conduct multiple HiL simulations. And the necessity of HiL testing of hybrid powertrains is more pronounced because of the interdisciplinary nature.

Vital: highly-robust communication networks

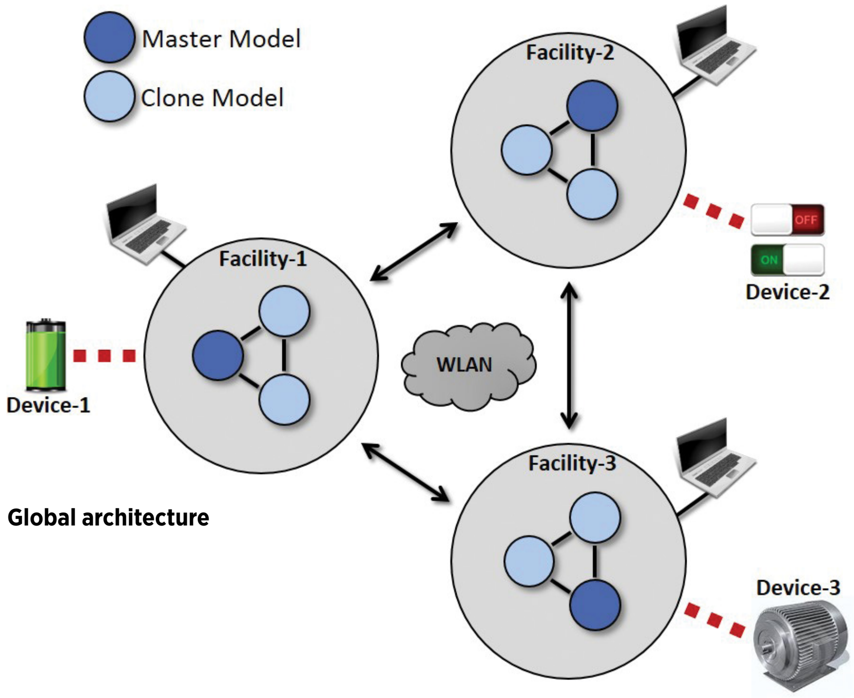
But there are challenges to be addressed before this can see the light of day.

First, non-robust connectivity with high latency could cause any co-simulation exercise to fall apart. Hardware simulation has the limitation that it can be done only in real time, since a device cannot be asked to react or behave "slower" than usual; but real-time simulation requires very high speeds of communication without delays.

The round-trip time for single packet of information may be more than 15 milliseconds using Google servers, for example. When there



Master-slave approach



Global architecture

are more than two segments of communication, the added complexity of causality is introduced. What if a packet of information from A reaches C significantly later than it reached B, and B has already reacted to the packet before C could respond?

The second challenge is more technical in nature. A hybrid powertrain deals with energy flowing between multiple domains: electro-chemical in battery, electro-mechanical in the motor, mechanical in the engine, transmission and wheels; the thermal loop exchanges energy, via coolant, from each unit that deals with power. Moreover, the control strategy must account for the complex interface between each of the powertrain's elements.

So not only is data exchange at an appreciable quality very challenging, selecting the variables that need to be exchanged for accurate communication adds an extra dimension.

Consider one simple example: the energy flow loop from battery to motor and subsequently to the wheels. During step-up, a voltage signal is sent from battery to motor; the motor reacts by drawing a certain amount of current to produce torque for the wheels. The electrical circuit is very dynamic and requires extremely high-speed communication—preferably in nanoseconds—a speed clearly not possible with existing networking capabilities.

The voltage output from the battery not only depends on the reaction current but also on the load torque experienced by the motor. Complexity escalates when seen at a system level, when questions arise: should the motor model send load torque information, rather than reaction-current information, back to the battery to make the simulation more resilient to network latencies and lost packets?

So exactly emulating the physical network by means of a virtual interface might not be the way to go. If communication networks could transfer data packets instantly and without loss, that solution might be viable.

The "slave" alternative

Instead, upstream and downstream models are needed at each testing facility, emulating the corresponding hardware at the remote location. These "slave" models should be capable of instantly predicting the behavior of the remote hardware. Then these predicted values would be routinely corrected and updated via communication packets received from the remote facility at a rate dictated by the network quality.

Further, it can be reasonably expected that the entire framework—i.e. which variables to exchange, rates of exchange, slave-model algorithms and other factors—is highly dependent on the network quality. For a product to survive in this dynamic world, it should be robust and scalable and capable of functioning with an ultra-fast fiber-optic network as well as with a public internet connection.

To achieve this, the dependency on data exchange needs to be studied. This could answer concerns such as whether it is worth co-simulation of multiple remote HiL tests given the available network infrastructure, or whether it would be preferable to simply build software models and simulate everything in single location.

Another chief consideration then arises: what would be the minimum quality of a network needed to achieve an incremental overall benefit from a multi-location setup? A generic standard for quantifying a given network has to be developed, generating a network "score" that then could be correlated to the capability and degree of accuracy of a remote co-simulation setup.

An interesting aspect of this project is that it is not just interdisciplinary within the automotive realm—an extra dimension of networking and communication is also introduced. The challenges can be addressed by strong collaboration between different centers of excellence to address this as a mutual goal.

Author: Surojit Sen is a PhD student in electrical and electronics engineering at the University of Nottingham and is working on a project called the "Virtually Connected Hybrid Vehicle," a collaboration between the UK government, UK automotive industry and several UK universities that are centers of excellence for different components of the hybrid powertrain.

FUNCTIONAL SAFETY–

Progressing towards safer mobility

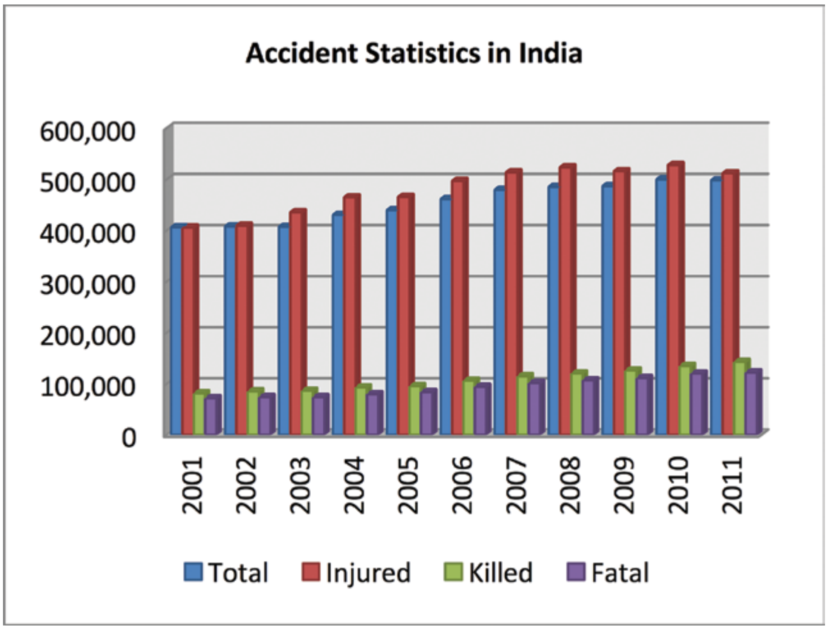


Figure 1. Accident Statics in India.

Abstract

Increasing complexity in E/E architectures poses several challenges to developing comfortable, clean and safe vehicles. This mandates robust processes to mitigate potential hazards due to malfunction of electronic systems throughout the product lifecycle. With the advent of ISO 26262, which provides guidelines for developing safe cars, the process is becoming standardized towards safer mobility. In this paper, the functional safety process is briefly covered and a case study of Hazard Analysis and Risk Assessment for specific E/E system is presented. An in-house tool developed for functional safety process and management also is presented.

Introduction

As per data published by Ministry of road transport and highways (government of India), the number of accidents is increasing year-on-year. It is disheartening trend, considering that today's vehicles are equipped with many and more-sophisticated safety features than ever before.

Today's customer demands more comfort and convenience features and wants to remain connected to the outside world, posing challenges for OEMs that have to deal with the increased complexity of E/E architectures. Over the past 15 years at **Mahindra & Mahindra**, E/E complexity increased many-fold. The Scorpio, for example, by 2009 transformed from a SUV with basic features to the most-advanced India-made SUV in the country. When the XUV500 was launched in 2011, it used the most complex E/E architecture ever used for a Mahindra & Mahindra vehicle.

Hazard analysis & risk assessment (HARA)

To ensure that all related hazards and risks related to a particular E/E component malfunction are analyzed, the first step is to totally understand the component's functionalities. The ISO 26262 standard states that "item definition" shall be the premier step. By definition, an item is a "system or array of systems to implement a function at the vehicle level, to which ISO 26262 is applied."

Item definition considers the functional requirement of the item, environmental conditions, legislative requirements, the elements of the item and the requirements relating to other items. Presented here is the item diagram of an engine start/stop function (see figure 2):

HARA is an extensive brainstorming activity that helps us to arrive at the safety goals of our system. It involves safety experts, system teams and components owners. Hence it must be ensured that human errors do not lead to contradicting results in the FSC. An automated tool helps to complete the task in an efficient manner and with the expected quality.

The Severity, Exposure and Controllability are rated for a malfunction event considering an operating scenario. Severity refers to the extent of harm to one or more individuals that can occur in a potentially hazardous situation; S0, S1, S2 and S3 are the four severity classes.

Table 1. Severity Classes.

S0	S1	S2	S3
No injuries	Light and moderate injuries	Severe and life threatening injuries (survival probable)	Life threatening injuries (survival uncertain), fatal injuries

Meanwhile, Exposure Class estimates the probability of exposure of each operational situation. This estimate is based on a defined rationale for each hazardous event. There are five probability classes: E0, E1, E2, E3 and E4, with the probability of exposure assigned to one of the probability classes.

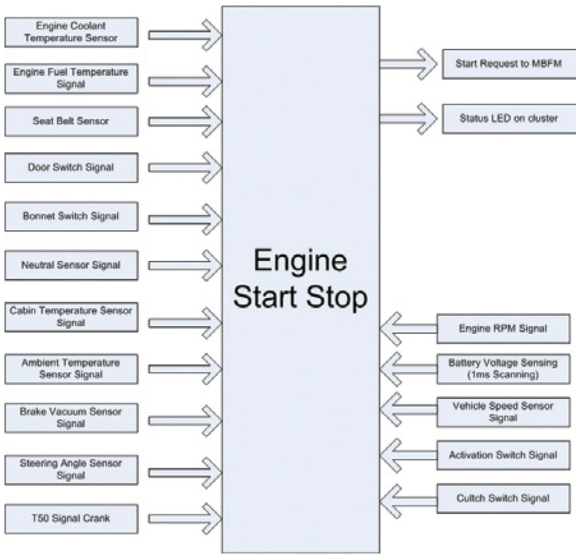


Figure 2. Item definition for engine the start/stop Functional Safety Concept (FSC) tool.

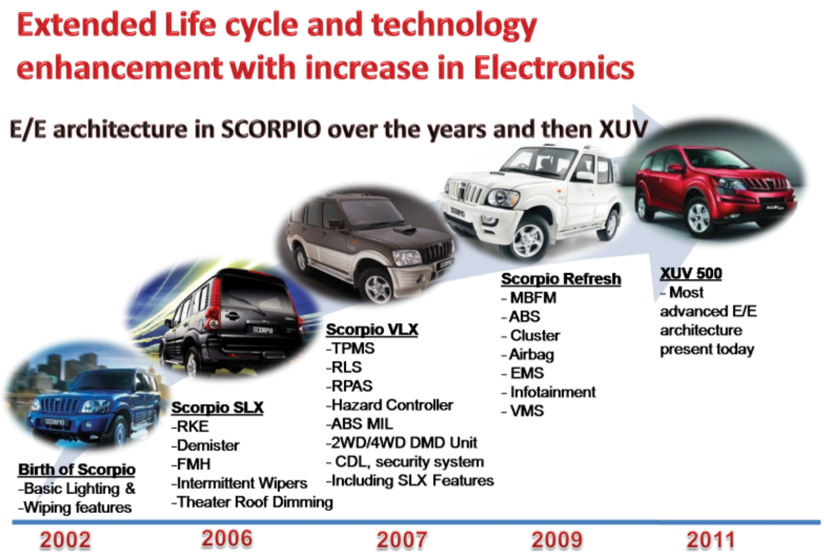


Figure 3. Technology enhancement over the years: the numbers of circuits, networks, sensors and actuators has increased drastically and are interfaced to a multitude of different ECUs.

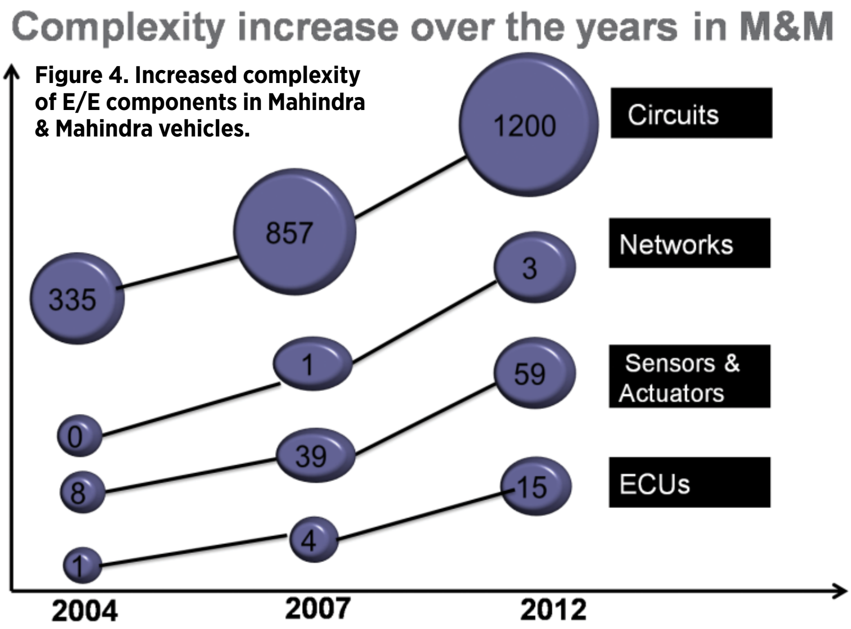


Figure 4. Increased complexity of E/E components in Mahindra & Mahindra vehicles.

Table 2. Exposure Classes.

E0	E1	E2	E3	E4
Incred-ible	Very low prob-ability	Low prob-ability	Medium proba-bility	High proba-bility

The Controllability Class is measured from the perspective of to what degree the driver is able to control the hazardous event.

Table 3. Controllability Classes.

C0	C1	C2	C3
Controlla-ble in gen-eral	Simply control-lable	Normally control-lable	Difficult to con-trol or uncon-trollable

An in-house tool has been developed for performing the FSC activities. Once the item definition is completed, the next step is HARA. An example for the HARA of the engine start/stop (micro-hybrid technology) function is illustrated below.

Function: Engine start/stop (Micro Hybrid Technology)
Malfunction: Unintended engine start

Operating Scenario 1: car stopped at red traffic light with a pedestrian crossing:

Table 4. Hazard: NH1.

Severity: S2	Exposure: E3	Controllability: C2	ASIL
Collision with pedestrian at low speed	E4: Waiting at red traffic light. E3: Pedestrian crossing	Driver can brake	A

Operating Scenario 2: garage operation with T15 on:

Table 5. Hazard: NH2.

Severity: S2	Exposure: E2	Controllability: C3	ASIL
Injury to me-chanics or op-erators nearby	E2: Garage opera-tion with T15 ON	Operator has less time to react	A

Operating Scenario 3: parking vehicle in the city:

Table 6. Hazard: NH3.

Severity: S2	Exposure: E2	Controllability: C3	ASIL
Possible front collision with front vehicle or obstacle	E3: Parking vehicle in city. Reduced to E2 as T15 & T50 should also be ON with gear in non neutral position and parking brake inactive	Uncontrollable because no driver in the car	A

Operating Scenario 4: parking in an underground garage:

Table 7. Hazard: NH4.

Severity: S2	Exposure: E1	Controllability: C3	ASIL
Possible front collision with front vehicle or obstacle	E2: Parking vehicle in city. Reduced to E1 as T15 & T50 should also be ON with gear in non neutral position and parking brake inactive	Uncontrollable because no driver in the car	QM

The overall ASIL for a particular function is the maximum of the ASILs assigned to different hazards associated with that function *(editor's note: due to space limitations, not shown here are the original paper's charts relating to unintended engine stop)*.

Table 8. Hazard-Code Reformulation.

<table>
<tr><th>Malfunction</th><th>Hazard Code</th><th>Individual ASIL Rating</th><th>Overall ASIL Rating</th></tr>
<tr><td rowspan="4">Unintended engine start</td><td>NH1</td><td>A</td><td rowspan="4">A</td></tr>
<tr><td>NH2</td><td>A</td></tr>
<tr><td>NH3</td><td>A</td></tr>
<tr><td>NH4</td><td>QM</td></tr>
<tr><td rowspan="3">Unintended engine stop</td><td>NH5</td><td>QM</td><td rowspan="3">QM</td></tr>
<tr><td>NH6</td><td>QM</td></tr>
<tr><td>NH7</td><td>QM</td></tr>
</table>

The in-house tool provides automation for deriving the ASIL ratings. Consistency also is achieved: severity, exposure, controllability classes are mapped in a way that prevents supplying contradicting values.

Safe states and safety goals are derived for each of the hazards.

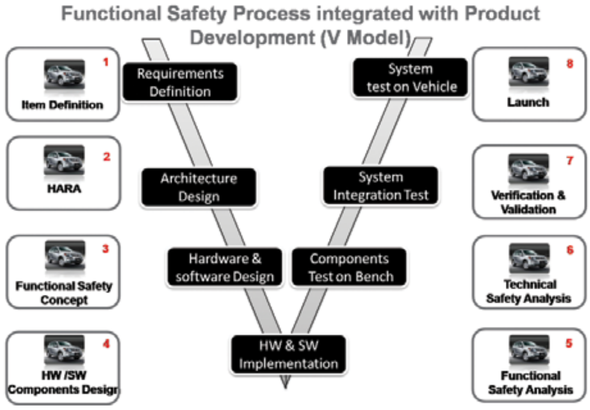


Figure 5. Functional Safety and V Model. Functional safety standard ISO 26262 provides a systematic approach to avoid unacceptable risks and guides at every stage of product development, represented by this V model.

Functional Safety Requirements (FSR) are derived from these safety goals. These FSRs are further mapped component wise and are given to the vendors as a work product of FSC. The supplier implements the FSRs and prepares the Technical Safety Concept, which is further reviewed by the OEM. In this fashion, the functional safety activities are carried out in a robust manner to ensure that the car is complying with the safety standard ISO26262.

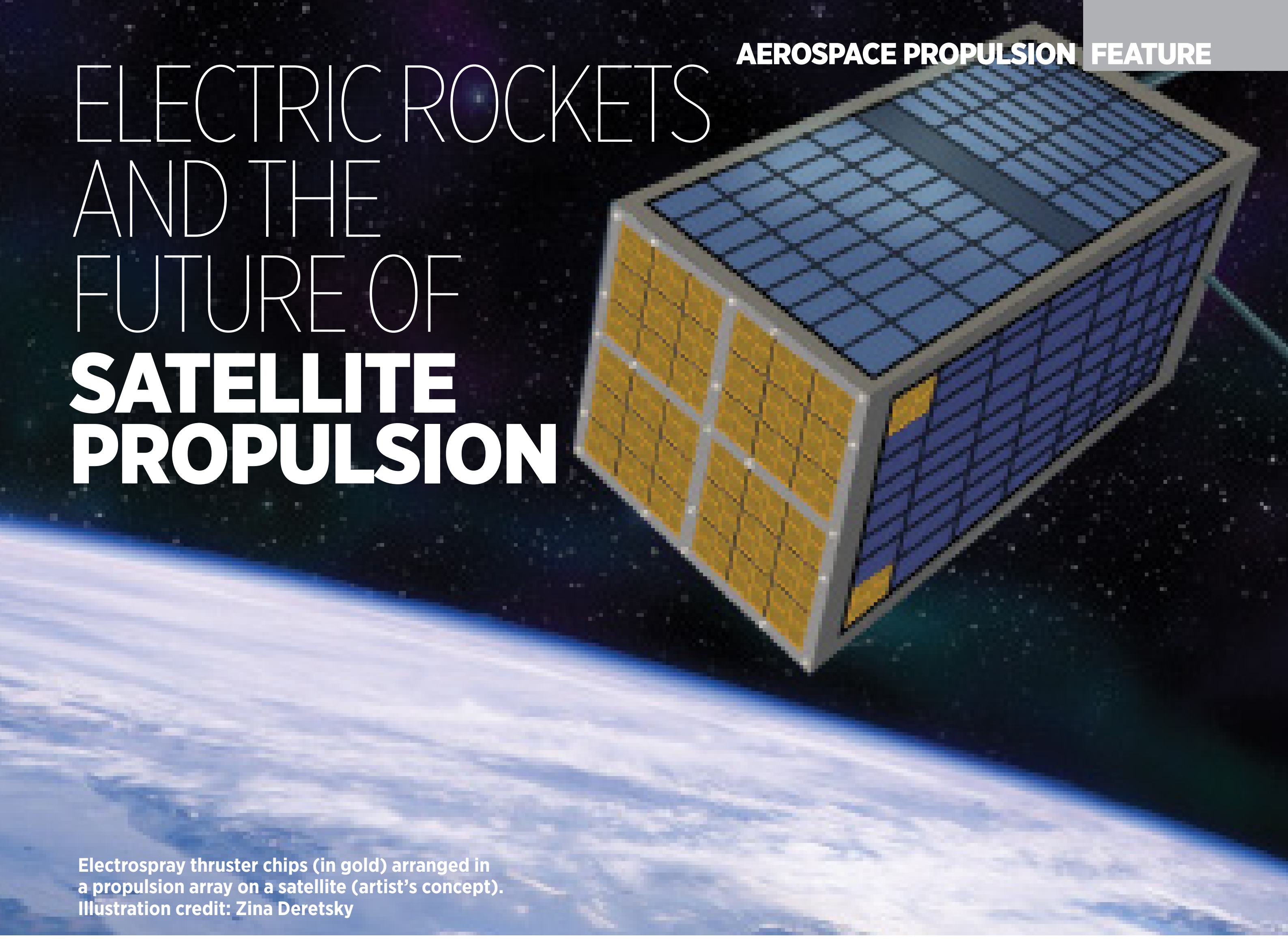
Summary/Conclusions

The reliability levels of electronics functionality may be compromised due to random hardware failures or systematic errors, so it is inevitable that a robust process needs to be institutionalized to ensure the reliability levels throughout product lifecycle.

A case study of hazard analysis for an engine start/stop system using the developed functional safety tool was developed and presented in this paper. The operating scenarios considered in this paper are based on initial studies and need further validation. Also, the safety goals and ASIL levels were summarized. Similar analysis is required for all electronic systems and safety-goals requirements to arrive at vehicle level from which safety requirements need to be defined and communicated with suppliers. The functional safety concept provides a systematic approach for estimating the risk levels and determining the redundancy levels which will reduce the hazards in the product lifecycle of the vehicle—all leading to safer mobility.

This article is based on SAE technical paper 2013-01-2841, authored by Srinival Aruapalli, Sunayana Kaushik, Abhishek Gupta, Nandagopalan Chidambaram and Prabaharan Palanivelu, all of Mahindra & Mahindra.

ELECTRIC ROCKETS AND THE FUTURE OF SATELLITE PROPULSION



Electrospray thruster chips (in gold) arranged in a propulsion array on a satellite (artist's concept). Illustration credit: Zina Deretsky

Humans have been using rocket propulsion for almost a millennium, starting with Chinese rockets and "fire arrows" in the 13th century and continuing to the modern era's powerful Space Shuttle and Falcon rockets. For most of that history, rockets have been chemically fueled, but in the past century scientists and engineers have also experimented with electric rockets, also known as ion engines or ion propulsion systems.

Rather than using chemical reactions to create heat and accelerate a propellant, electric rockets use electromagnetic or electrostatic fields acting on charged ions of propellant, speeding them up and shooting them out, away from the vehicle, producing thrust. The electrical energy to generate these fields comes from the sun, from batteries, or both.

Ion engines might sound like something you'd find on the Starship Enterprise, but in fact they've emerged as a practical solution for in-space maneuvers. **NASA**'s Deep Space 1, launched in 1998, demonstrated the sustained use of an ion thruster in space. The most recent version of **Boeing**'s 702 satellite bus uses an all-electric propulsion system for orbit transfer and maneuvering the satellite once it is in orbit (prior versions used hybrid chemical and electric engines).

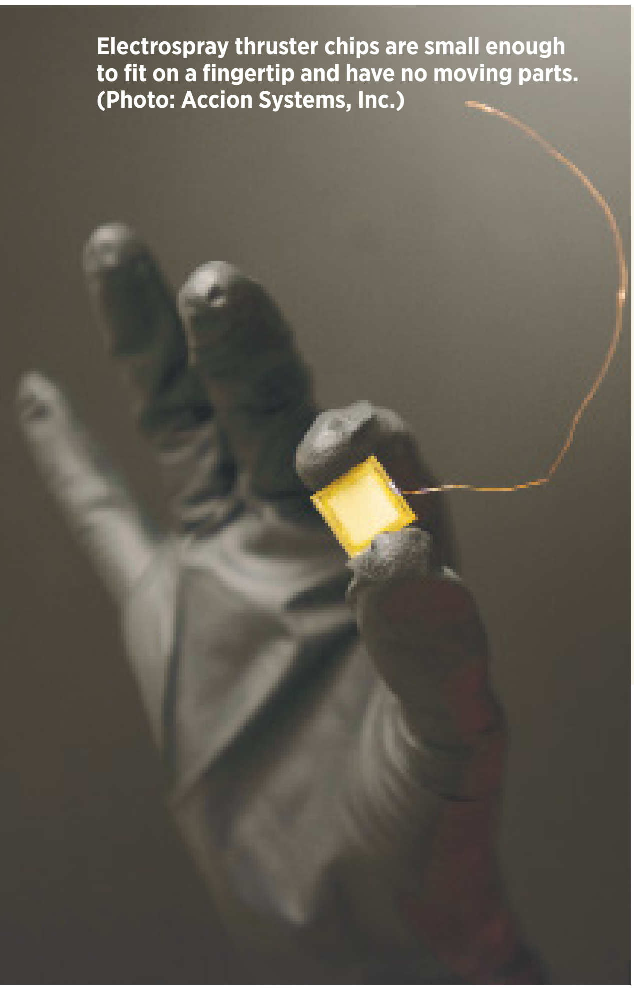
Electric rocket engines are far less powerful than chemical rockets, so they can't be used to launch rockets into space. But once in orbit, they have some big advantages: They're far more efficient, per unit of propellant mass, than chemical rockets. And because they rely on electricity, they can be powered by solar panels.

Accion Systems, Inc. has developed an electric rocket system, based on electrospray propulsion technology, that can be made to work at a far smaller scale than previous ion engines. It's also cheaper and easier to manufacture these thrusters in large numbers. That makes them well-suited to deployment on small satellites and nanosatellites, where these engines can help maintain orbit, change a satellite's orientation, or even move it to a different orbit with great efficiency.

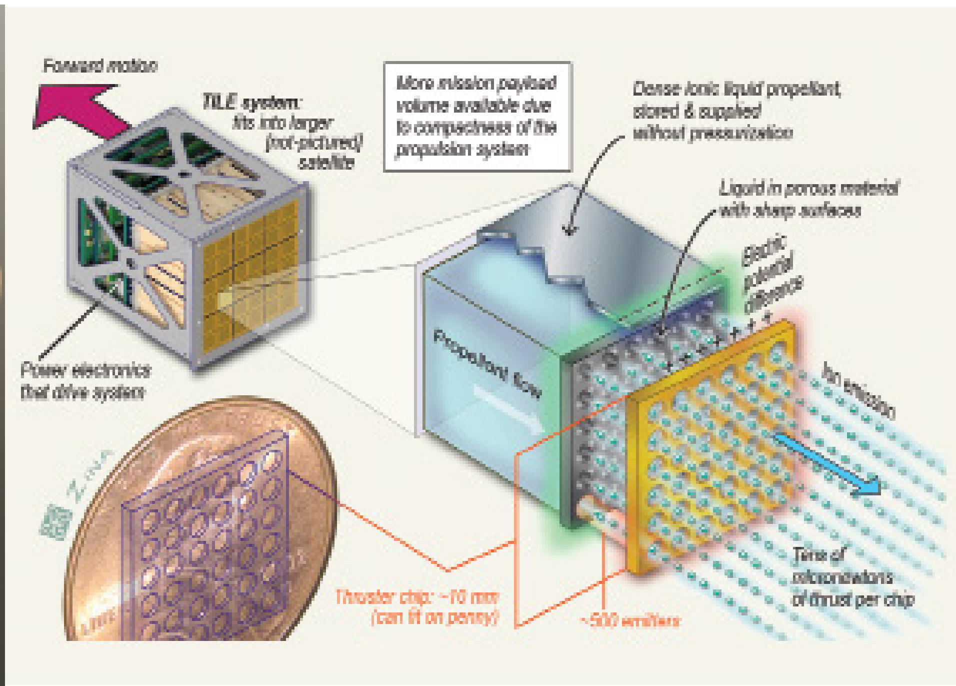
Electrospray propulsion: how it works

Research into electric rockets began in earnest in the mid-20th century as part of the "space race." Eventually, two main types emerged. In the Soviet Union, "Hall thrusters" saw some limited operational use in the 20th century. In the United States, "gridded ion engines" were a subject of experimentation but were not widely deployed until recently, as part of Boeing's Xenon Ion Propulsion System (XIPS), the electric propulsion system used on the company's Boeing 702 satellite bus.

A third type of electric rocket technology, electrospray propulsion, didn't proceed past



Electrospray thruster chips are small enough to fit on a fingertip and have no moving parts. (Photo: Accion Systems, Inc.)



How the TILE system generates thrust (Illustration: Zina Deretsky).

the experimental stage in the 1960s and 1970s. However, research in the past decade by Paulo Lozano at **MIT**, assisted by Natalya Brikner and Louis Perna, pushed electrospray from theory into reality. (Perna and Brikner were graduate students under Lozano's supervision and are the cofounders of Accion Systems.)

The basic idea with electrospray propulsion is that you start with a conductive liquid and expose it to a strong electric field. That field brings charged ions to the surface, deforming the surface of the liquid and pulling it up and away from the rest of the liquid. As the liquid deforms, it extends into stronger parts of the electric field, deforming it still further, and so on. Eventually the field pulls a tiny droplet (or even a single ion) off the very tip of the deformation, accelerating it out and away, generating thrust.

Recent innovations

Building on the MIT research, Accion has advanced electrospray propulsion in several ways. First, it uses a conductive liquid as a propellant—a compound that's liquid at room temperature and which contains two different molecules (one positively charged and one negatively charged). Because this propellant already contains charged ions it doesn't need to be ionized, which is why the engineers dub it "plasma in a bottle." By contrast, other ion engines require an ionization step prior to accelerating the ionized propellant.

Second, the propellant is stored within a porous material, which brings the liquid into the thruster's electric field through an array of sharp microstructures on its surface. The porous material acts as a wick, drawing the propellant out of a reservoir and into the thruster. The microstructures pre-deform the liquid, so the electric field need only operate at the tips, pulling out the liquid still further and extracting it a few ions or molecules at a time.

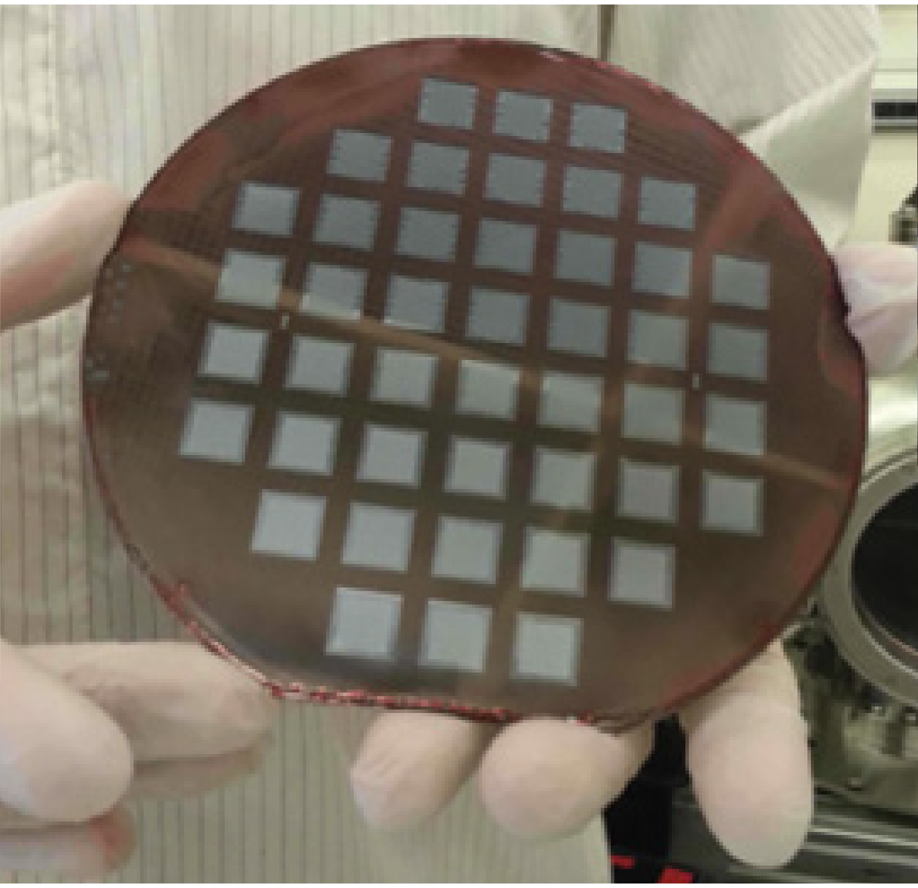
Third, the extractor (the part that generates the electric field) is made with micro-emitter holes that line up with the microstructures on the porous material. Its field is designed to extract ions from each tip separately. Altogether, a single thruster chip is about the size of a U.S. penny, but contains hundreds of emitters, all firing in the same direction.

It's not very powerful: Each penny-sized chip generates only a few tens of micronewtons of force—approximately equal to the force exerted by a mosquito's wings. But the technology has substantial advantages that can make up for its low level of force.

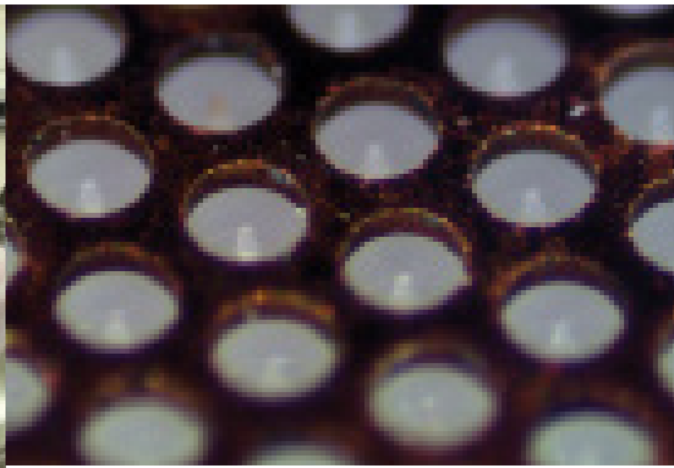
Electrospray propulsion: pros and cons

Ion engines, including electrospray propulsion systems, have excellent specific impulse—a measure of propellant mass efficiency. So while their thrust is weak, they use propellant extremely efficiently. That means they are well suited to applications where the time required to accelerate is not as important as the overall mass of the satellite.

For unmanned satellites, that tradeoff is easy to make. More efficient propulsion means you don't need to devote as much of the satellite's mass to propellant, leaving more room for the payload—or making the overall satellite less massive and therefore cheaper to launch. Meanwhile, if it takes days or weeks to complete a maneuver, that's not a problem for the satellite's computers: They can just wait patiently.



Accion's chips can be manufactured with techniques used to manufacture silicon chips and MEMS devices (image: Accion Systems, Inc.).



This closeup shows the emitter tips immediately behind an array of holes in the electrically charged extractor (image: MIT Space Propulsion Laboratory).

Because the propulsion system can act on the conductive liquid directly, power is not needed to ionize the propellant.

What's more, this liquid is extremely non-volatile, which means it's relatively safe to handle. It emits no dangerous vapors. If you spill some of it on a surface, it will just sit there, without evaporating, for years.

It doesn't even evaporate in the vacuum of space, which leads to another benefit—because the propellant has such a low evaporation rate and is liquid at a wide range of temperatures, it doesn't need to be compressed, as do the gas propellants used by other ion propulsion systems. That eliminates the need for bulky, massive, thick-walled compression tanks.

The Accion system contains no moving parts, making it extremely reliable. No pumps or valves also reduce the power demands and the overall mass of the system.

It can also be manufactured en masse, using techniques developed for the semiconductor and MEMS industry. In contrast to the labor-intensive "bespoke" approach used to manufacture other types of rocket engines, these engines can be built in a largely automated way. This makes it possible to manufacture dozens or even hundreds at a time.

Electrospray technology has power efficiency comparable to other ion thrusters, with about 40-50 percent of the power used being converted to thrust. But the theoretical efficiency could be much higher, on the order of 90 to 95 percent, and as the technology improves it should get closer to the theoretical limit.

For microsatellites and nanosatellites, this version of electrospray technology has one particular advantage—it can be very small. Other types of ion propulsion systems show a dramatic loss of efficiency at extremely small scales. But this system, at its smallest, can be contained in the space of a golf ball or even a stick of gum. To generate more thrust, satellite makers can simply put together multiple chips in grids of any needed size.

However, as mentioned above, electrospray thrusters are extremely weak, generating only a few tens of micronewtons of force. (A micronewton is the force required to accelerate one gram by one millimeter per second, per second.) That precludes them, like other types of ion thrusters, from use in applications where it is important to complete acceleration quickly.

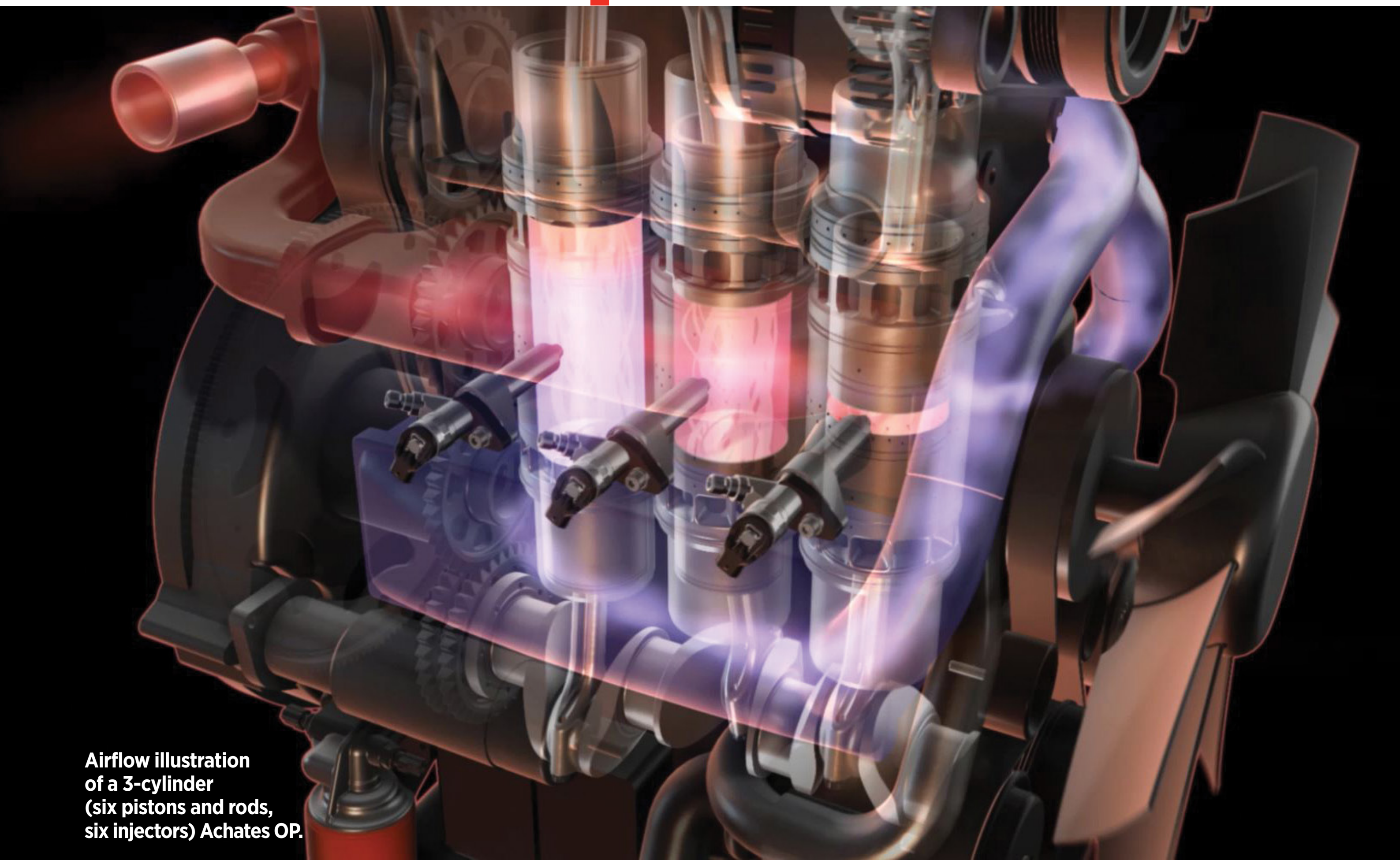
In terms of thrust density (thrust per unit area) electrospray thruster chips are comparable to those of Hall thrusters and gridded ion engines, and far weaker, of course, than chemical rockets. Theoretically, however, they can reach thrust densities up to 10,000 times higher than at present, with improved manufacturing techniques.

The technology is new and relatively unproven. Electrospray thrusters based on the MIT research are currently being tested on two satellites in space.

Finally, one "disadvantage" is that electrospray propulsion chips just aren't that exciting to look at. There are no thruster nozzles. The emitted ion stream is not visible, so there's no dramatic exhaust to look at. The gold thruster chips just sit there, exposed to space, silently and invisibly emitting ions that gradually accelerate or rotate the satellite as needed.

This article was written by Natalya Bailey, CEO and founder, and Louis Perna, Mechanical Systems Team Leader and co-founder of Accion Systems (Boston, MA). For more information, visit http://info.hotims.com/65850-502.

ACHATES POWERS toward production



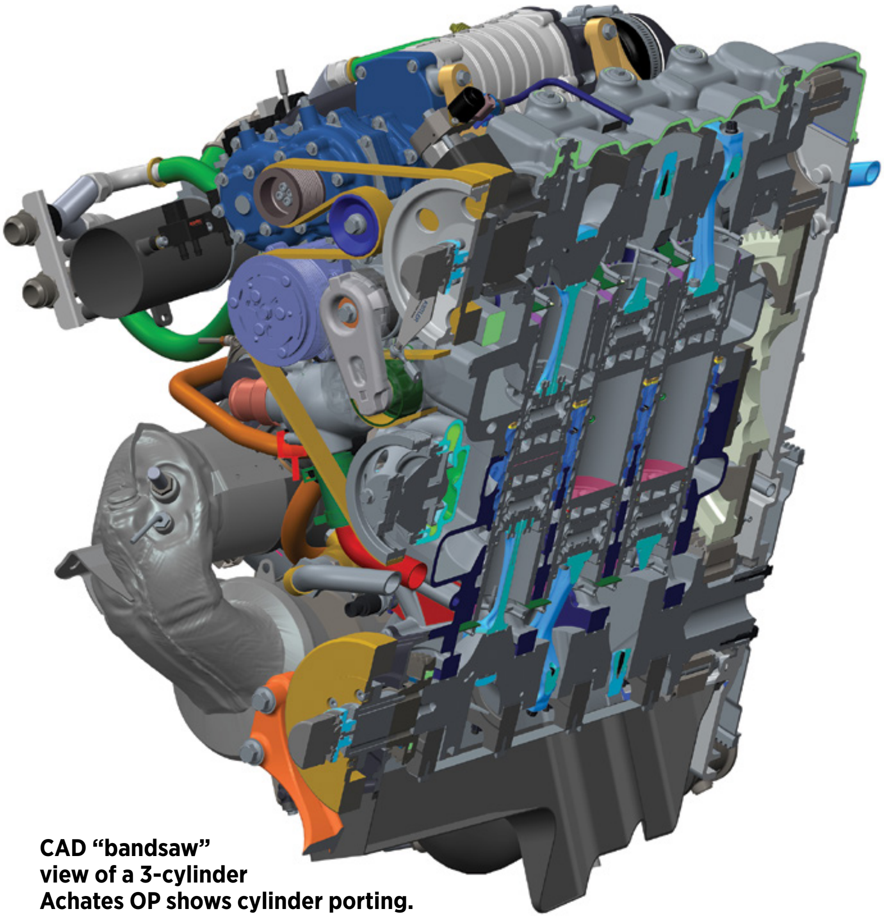
Airflow illustration of a 3-cylinder (six pistons and rods, six injectors) Achates OP.

A potential ICE game-changer, the Achates OP engine is being tooled up for production at one OEM while a new 2.7-L triple for light-truck demonstrations enters the build phase.

by Lindsay Brooke

Nothing short of a game-changing technology has any chance of disrupting the world's combustion-engine mainstream, it is generally believed. Felix Wankel's rotary came the closest, carving out a successful niche at **Mazda** after **GM** spent millions tooling up for, then killing, its own high-volume rotary program in the 1970s. Now comes **Achates Power**, the San Diego technology company that has brought its opposed-piston, 2-stroke, compression-ignition engine to the brink of production after 13 years of careful and relentless development.

At January's 2017 Detroit auto show, Achates' top engineers made two promising announcements. First, one of the company's nine global OEM customers has begun tooling an engine plant for serial production of an Achates 'OP' engine. While no details or timing were provided, Achates' current customer base includes applications for passenger-vehicle, light and heavy commercial vehicle, military and marine/stationary power. The engine programs span a broad range of fuel strategies and configurations—from 50-hp (37 kW) single-cylinder units to 5000-hp (3768-kW) twelve-cylinder monsters aimed at stationary and marine use. Development also includes a gasoline compression-ignition program (see sidebar).



CAD "bandsaw" view of a 3-cylinder Achates OP shows cylinder porting. These engines have wet-sump crankcase lubrication and plain bearings similar to a 4-stroke.

One of Achates Power's dyno cells at the San Diego headquarters, which continues to expand (images for both pages: Achates Power).

Achates CEO David Johnson also reported that a new 2.7-L 3-cylinder diesel unit—each OP engine has two pistons and con rods per cylinder, driving two geared crankshafts—is entering the build phase. A batch of engines will then start clocking dyno time in preparation for light-truck on-road demonstrations and customer evaluations in 2018. Turbocharged and supercharged, the 2.7-L will be capable of delivering 270 hp (201 kW) and 479 lb·ft (650 N·m) at crankshaft speeds comparable to current-production light-duty diesel engines, he said.

The demo units, their fully-dressed package volume and mass equivalent to that of **Ford**'s 2.7-L Ecoboost V6, will be installed in full-size pickups and/or SUVs—the market segment Achates is promoting for its volume, profit and CAFE-impacting potential, Johnson explained. The 2.7-L "will be fully measured and characterized and will achieve 50% improvement in fuel economy versus downsized, turbocharged, spark-ignited gasoline engines today." It will also be 30% more efficient than the best incumbent passenger-vehicle diesels, he said.

Johnson quoted a 37-mpg (unadjusted) CAFE number for the engine; 2025 U.S. regulations call for vehicles with a 65-70-ft2 'footprint' to deliver 33 mpg. City/highway/combined EPA fuel economy for an Achates-powered base truck calculates at 25/32/28 mpg.

"We'll have a 'CAFE-positive' vehicle," he asserted. Johnson, a veteran of GM's global diesel engineering and Ford truck product planning before joining Achates Power in 2008, also is confident the 2.7-L six-piston OP diesel will meet the federal Tier3 GHG fleet average of 0.03 g/mile NMOG + NOx with minimal tradeoffs in BSFC. Upcoming Euro6 standards also are achievable he said.

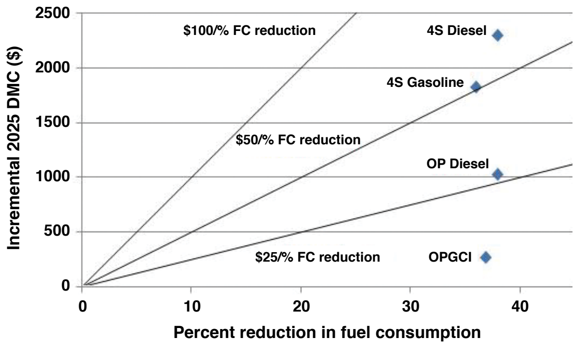
Development work conducted with **Johnson Mathey**, **Emitec** and other aftertreatment-system suppliers project the OP engine's aftertreatment-cost burden to be 30% less than current-production light-duty diesels, according to Johnson. Smaller catalysts (with less precious-metal content) are required due to the OP's comparatively low engine-out NOx emissions.

Particulate formation is inherently reduced due to the OP's injection environment, the engineers claim. Two injectors per cylinder, fed by a 2000-bar common rail, spray fuel across the cylinder bore perpendicular to piston travel towards top-dead center. Fuel droplets therefore "do not impinge on the combustion chamber wall, dramatically reducing soot formation. As we run, test and measure our engine, we find its soot production to be low. We have tremendous datasets [regarding PM] with our diesel," Johnson explained. He expects, though, that Achates' gas and diesel engines will at some point require PM filters.

Traditional 4-stroke gasoline ICEs are least efficient during low-speed/low-load operation—the region where most drivers spend most of their time. Rondon noted that Achates' OP engine has demonstrated its ability to minimize the efficiency drop at low loads; where traditional 4-strokes' pumping comes from their systematic "suck-spark-bang-wheeze" cycling, the OP's supercharger, currently an **Eaton** unit, provides independent cylinder charging. It can be adjusted to supply precisely the amount of air needed per quantity of fuel injected, providing what Rondon calls an advantage over the incumbents in low-load/low-speed running.

The operating characteristics, inherently good primary balance and steady-state emissions profile also lend themselves to hybrid applications; Johnson noted that Achates has a study underway for a small-displacement

ACHATES POWERS
toward production



Achates 2017 plot showing how the OP engine compares on value-for-fuel economy.

(600cc-700cc per cylinder) range extender.

"Our opposed-piston engines are the most cost-effective, fuel-flexible, power-and-torque-dense solution for OEMs to meet the CO2 and fuel economy regulations of the next decade, without having to change the world's fuel infrastructure," Johnson told *Automotive Engineering* in December 2016 during a visit to his company's headquarters.

$1000/unit cost savings

The industry's expanding interest in Achates Power OP developments includes work with **Cummins** on the **U.S. Army TARDEC** Advanced Combat Engine, a single-cylinder demonstator, plus programs with **Fairbanks-Morse** and the ARPA-e OPGCI project with **Delphi** and **Argonne** noted in the sidebar.

The engineering team's enthusiasm continues to grow with each week of testing and development. "There was a time when I joined Achates Power that I didn't know if the technology would work or not," Johnson admitted. "Now, I have absolutely no doubt we'll get into volume production. When we started, top powertrain engineers from major engine companies said to me, 'You'll never be able to achieve good combustion with this engine.' So we went to work on that. We solved that problem and patented the solutions and demonstrated them. We did the same with NVH." Achates currently owns 120 patents on the OP engine with another 200 pending.

Company founder Dr. James Lemke saw significant advantages in the basic OP 2-stroke design that has powered aircraft, ships and military vehicles since the 1930s. He believed that clean-sheet re-engineering and application of the latest technologies could boost the OP's historic attributes—low heat rejection, high expansion ratio, lean combustion and reduced pumping losses—and reinvigorate the engine for 21st century propulsion duty.

For background, see our June 3, 2014 feature

CEO Dave Johnson (left) and development chief Fabien Redon with an OP cylinder. (Lindsay Brooke photo)

article, available for download at http://magazine.sae.org/14autp06/. Also see SAE Technical Paper, "An Analytical Assessment of the CO 2 Emissions Benefit of Two-Stroke Diesel Engines," Alok Warey GM R&D, et al, http://papers.sae.org/2016-01-0659.

Many factors contribute to Achates' claimed $1000 to $1500 per-unit cost savings for its OP engines versus comparable current LD gas and diesel engines, explained Fabien Redon, Vice President, Technology Development. Bill-of-material advantages are significant because there are no cylinder heads, gaskets, camshafts or valvetrain. Along with head machining, the head(s) and valvetrain typically account for 15-20% of the cost of a 4-stroke base engine. This more than offsets cost of the OP's second crankshaft and supercharger, Redon said.

Compared with a state-of-the-art V6 with supercharger, the 2.7-L Achates OP's BoM is more than 60% smaller, enabling an approximate 10% cost reduction, he noted.

Engine assembly is simplified and there is minimal "all new" in the manufacturing process, the majority of which is shared with incumbent ICE production. The Achates' long stroke-to-bore ratio (typically 2.2:1) helps deliver strong output-torque characteristics that may lessen the need for 10-speed transmissions now emerging in the industry.

"Our fuel maps for both the gas and diesel engines are similar—and they're much flatter than those of other light-duty diesels, so we don't need all those [transmission] speeds," Johnson surmises.

And without a cylinder head, the OP rejects less heat to the coolant. The resulting lower radiator and fan loads mean those components can be reduced in size. A powertrain-engineering expert contacted by the author for comment, who is familiar with Achates' technology called the 2.7-L project "quite viable in virtually every metric to this stage."

OPGCI project pushes toward 50% BTE gains

In late 2015, ARPA-e, the **U.S. Dept. of Energy**'s Advanced Research Projects Agency, awarded a $13 million grant to Achates Power, **Delphi Automotive** and the **Argonne National Laboratory** (ANL) to develop, in a three-year program, a gasoline compression-ignition (GCI) version of the Achates Power OP engine. An OPGCI?

Delphi and Argonne had previously demonstrated that by combining high compression ratio and throttleless lean operating conditions, gasoline can be ignited and combusted without a spark plug. Cylinder temperature, pressure and fuel distribution must be precisely controlled, but the result is diesel-like torque and performance and claimed 50% greater brake thermal efficiency than current gasoline ICEs. Lower peak temperatures result in reduced NOx and there's less particulate formed due to mostly lean local mixture conditions in the cylinder. The higher hydrocarbon and CO emissions that result can be managed using an oxidation catalyst.

According to a report by Fabien Redon, VP Technology Development at Achates Power and Steve Ciatti, Principle Mechanical Engineer with ANL, the opposed-piston 2-stroke engine helps minimize the following technical challenges of GCI:

Mixture preparation and GCI Injection: Clean, robust GCI combustion requires a stratified charge, with locally lean and rich areas and multiple injection events. The Achates OP, with its diametrically opposed dual injectors spraying across the cylinder bore's combustion space, has advantages for charge stratification, the engineers explain. Each injector can be independently controlled and its events staggered for optimum mixture distribution.

Charge-temperature management: GCI requires higher temperatures for combustion at low loads, such as at idle or coasting. Engines operating in such conditions generate relatively little heat—a problem that worsens in small cylinders with high ratios of surface area to combustion volume. The Achates OP engine can retain exhaust gas in-cylinder, especially at low loads when relatively little new oxygen is required. Its in-cylinder scavenging is determined by the pressure ratio between the intake and exhaust manifolds.

At low loads, the Achates OP engine can reduce the supercharger work used to boost the intake manifold pressure. This reduces the amount of work by the supercharger, thus improving efficiency. In-cylinder temperatures remain high for good combustion stability. An internal EGR effect is provided for low-NOx combustion and high exhaust gas temperatures are created for rapid catalyst light-off.

High-load operation and pumping: GCI engines bring challenges under high loads that create tradeoffs. They require high air and EGR levels to control combustion—adding significant pumping work that erodes fuel efficiency. This also creates high cylinder pressures that can limit the engine's maximum-load capability and create combustion noise. The OP engine's 2-stroke combustion cycle, by comparison, reduces the maximum BMEP requirement (and displacement) while maintaining performance requirements. Reduced pumping work is due to the relatively large flow area of the OP engine's ports, more optimum turbocharger performance and efficient EGR pumping. Also, the OP's larger cylinder volume available for combustion enables faster heat release rates without increasing combustion noise.

Among the benefits of combining the Achates OP engine with GCI, the engineers noted the lower cost of the entire powertrain package versus diesel, due to a reduced aftertreatment (smaller catalysts) burden. Watch this magazine for an update on the ARPA-e project. **–LB**

The new 2.7-L three-cylinder OP is engineered for both gasoline and diesel fuels. Note cylinder axis slanted slightly for packaging, supercharger at top of image, and close-coupled catalyst at left center.

Oil consumption no issue

Like countless classic piston-port 2-stroke motorcycle engines, the Achates OP has its intake and exhaust ports in the cylinder walls—but with the intakes at one end of the cylinder and exhausts at the other. The ports are opened and closed by the piston motion, enabling "uniflow" air scavenging. But the piston-port design also was the Achilles' heel of those historic engines, contributing to excessive oil consumption as the piston/ring assembly drags the oil film past a port with every piston reciprocation. The term "oily mess" was probably coined by the black-coated **Detroit Diesel** 6-71 engines that powered every GM city bus.

That won't be the case with the Achates OP. Oil consumption is comparable with that of 4-stroke diesels, perhaps "a little bit above," Johnson claimed. "No exotic coatings or materials required. It's really about the details of the bore hone, port shape, ring tension and ring profile. All are critical and we've done a lot of work on them," he explained.

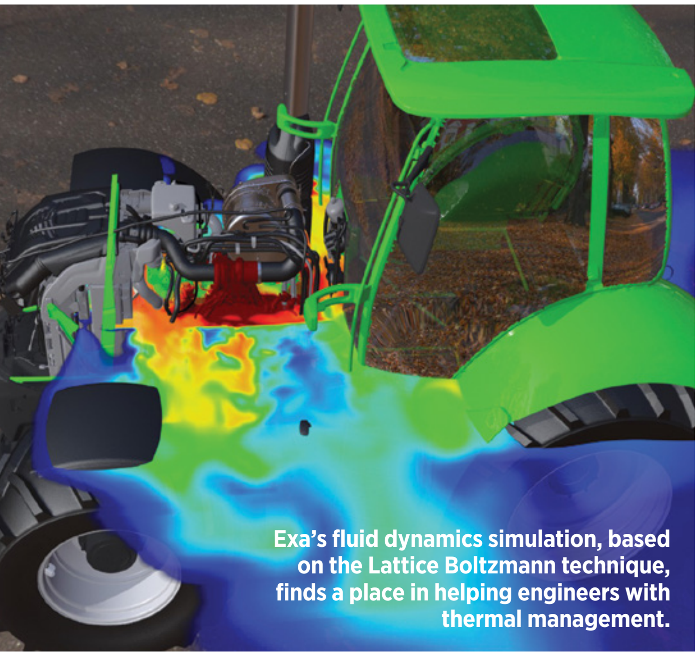
In 2010, Achates took delivery of a refinery gas analyzer from **Da Vinci Laboratory Systems** for measuring exhaust sulfur content. "It allows us to measure the real-time oil consumption while the engine's running," Johnson noted. "We create an oil-consumption map for any running engine within two hours. Change parts, new map. We've published papers on this."

Achates' next step is getting the batch of 2.7-L triples built and into customer dyno cells and demo vehicles.

"The big challenge for us is the protracted timelines of the engine business," Johnson said. "It takes a long time to start a new engine program and get to SOP (start of production). The good news is we have customers and more than 50% of the world's major engine companies have started a project with us. So we can begin to forecast when production is going to be."

Technically, the Achates Power engineering team doesn't see any major barriers. "We are bringing this engine forward toward production with our customers," said Johnson. "When you have all the customers that we do, it's now kind of a race." ■

ENGINEERING WITH SIMULATION AND DATA



Exa's fluid dynamics simulation, based on the Lattice Boltzmann technique, finds a place in helping engineers with thermal management.

Off-highway often looks at hybridization using hydraulic accumulators as well as mechatronics. CAE simulation from providers such as Siemens PLM is becoming a critical tool in developing these complex machines.

Companies are discovering new simulation techniques, especially optimization; the next step is to combine simulation with sensor data and predictive analytics to create even more robust off-highway equipment.

by Bruce Morey

Making off-highway equipment, such as construction or agriculture machines, more efficient continues to be a priority after the final phase-in of the U.S. **EPA** Tier 4 Final emissions regulations.

"Some of the companies we work with are running out of credits and unfortunately still struggling with Tier 4," explained Tristan Donley, Technical Director, Off-Highway Heavy Vehicles North American for **Exa**, a supplier of software for computational fluid dynamics (CFD). These companies continue to balance thermal and noise requirements due to their upgraded engines and aftertreatment devices, for example. "Others are now focusing on cutting the additional cost from components that enabled them to meet Tier 4 Final, but drove up the cost of their machines," she said.

A key element of this packaging is optimally managing thermal flows in systems that must be ever more efficient and smaller. That is where Exa's flagship software PowerFLOW enters the picture. PowerFLOW uses a relatively new technique in simulation, Lattice Boltzmann CFD. Without going into mathematical details, it claims advantages over the more common CFD based on continuous Navier-Stokes formulations, according to Donley. Using Lattice Boltzmann allows PowerFLOW to use a computational mesh with larger cells, or voxels as they term them.

"It is easier to resolve complex geometry and is inherently transient. Our voxels can be larger than the feature we are trying to predict the flow around," she said.

While the method is also useful for aerodynamic flows, off-highway engineers tend to use it mostly for aeroacoustics and thermal management. "The priority for our current customers is using optimization techniques for package layouts. They want to know space claims for different components such as heat exchangers, or how to orient the engine to protect electronics," she said. "They also want to know where to place grilles and louvers to make sure they get enough airflow through their engine compartment."

She notes that some of these companies had never used any type of CFD software prior to designing systems for Tier 4. There were so many challenges that their tried-and-true design techniques of the past—what she calls "tribal knowledge"—were not working, creating an opening for using advanced simulation like PowerFLOW's Lattice Boltzmann CFD. She also

Siemens PLM believes the industry is in the early stages of seeing an impact of sensors, data collection and analytics on the design process beyond simple predictive maintenance. Here, a prototype is instrumented as part of a test campaign. (Siemens PLM)

notes the increasing use of various optimization techniques, like multifunctional objectives and trade-off techniques that balance competing priorities for an optimum solution.

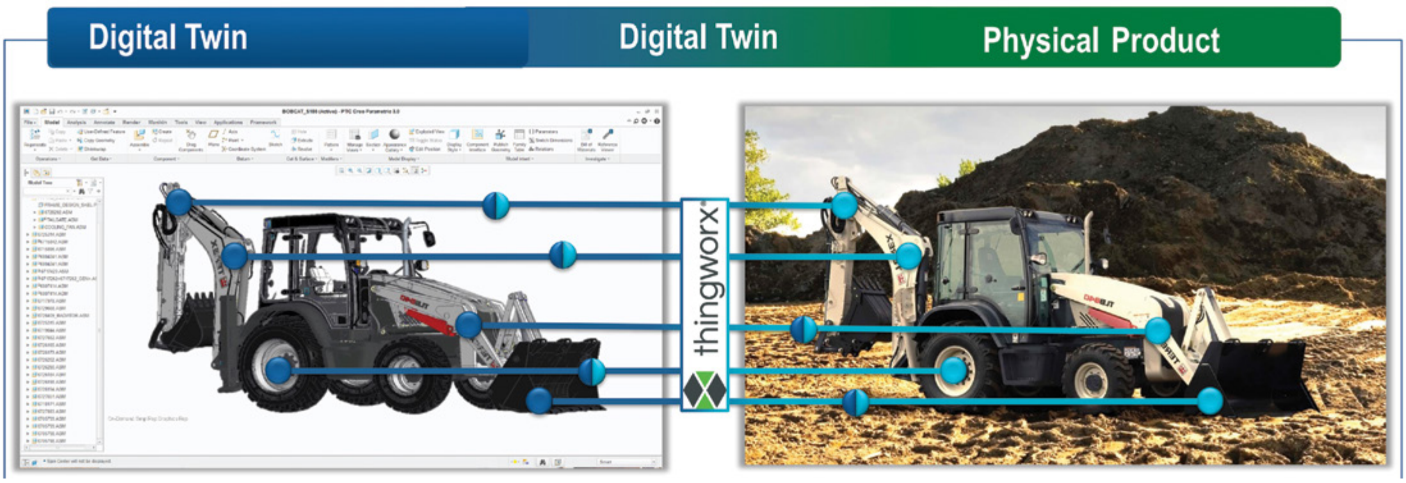
Integration and digital twins

At **PTC**, provider of CAD and simulation software as well as Internet of Things (IoT) solutions, "integration" is an important trend. The company's flagship CAD software, Creo, is tightly integrated with its finite-element simulation package, Creo Simulate, for performing structural, thermal and vibration analysis.

"There are many geometric design changes in the lifecycle of a design, and typically if you make that change you have to start the analysis process again," explained Jose Coronado, Product Manager for Creo Simulate. "With Creo Simulate, this is not the case. Whenever you change the geometry because you had to change the design requirement, the downstream settings are updated automatically."

He also touts the software as easy to use, with an interface designed for engineers without a deep background in advanced finite element analysis—no PhD required. "The user interface is common with Creo to make it consistent," he said.

While Creo Simulate adapts to design changes, Coronado points out that the use-case scenarios for setting initial conditions and loads often remain assumptions. How much weight will be in a bucket, how fast will



Establishing a digital twin through IoT communicators like ThingWorx brings even more reality to CAE simulations by incorporating actual test measurements into future analysis. (PTC)

Advances in urea deposit modeling

One of the key components for most off-highway engine makers to meet emissions regulations is selective catalytic reduction (SCR). These systems convert nitrous oxides, or NOx, into nitrogen and water. They require a separate fluid added to the exhaust gas. This is typically anhydrous ammonia, aqueous ammonia or urea, collectively referred to as diesel exhaust fluid (DEF). The conversion process requires a catalyst to complete.

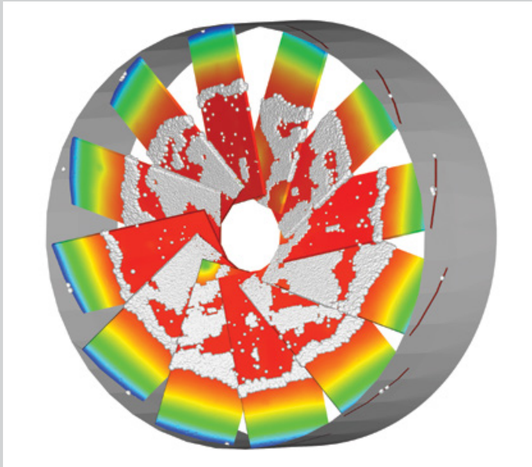
Long-term effectiveness and durability is greatly affected by unwanted formation of deposits. The systems work better if they remain clean and smooth. "Deposits are even more of a problem in the compact, low-temperature SCRs that are better overall at meeting requirements," said Scott Drennan of **Convergent Science**. "Everyone who uses SCR aftertreatment says deposits are their biggest concern."

Engineers would have valuable insight, and a cost-effective design tool, if they could use CAE simulation to predict where deposits might grow. It is a challenging problem, involving complex chemistry, phase change, and multi-phase CFD. Making modeling even trickier, according to Drennan, is that these deposits only form in a limited temperature range, above 433K or below 406K. "Most simulations to date will identify areas in the design where there is a risk that deposits will form," he explained, making analysis after the fact.

"We are now modeling the actual chemistry and moving to predicting where actual deposits will form," he said. The capability will be available in the next release of CONVERGE, the detailed chemistry and CFD code the company is known for. While predicting where they will form, it is still beyond the computational capability of any computer to predict how thick such deposits might be.

"However, it is a good tool to help people design more durable SCR," he said.

Bruce Morey



Predicting where deposits will form in SCRs using the CONVERGE CFD package. (Convergent Science)

the machine be driven, or how many hours a day will it be used are derived from spotty observations or educated guesses.

"Better is to establish a digital twin by integrating data from a physical product with a digital representation of that product. This will give us greater insight into the product's state, performance and behavior," he said. "We can use real loads in our simulations instead of assumptions."

Connected to embedded sensors, the company's ThingWorx product will facilitate transmitting real data to the designer of, say, a backhoe. The data will show if operators are lifting 2 tons or 5 tons, operating it 12 or 8 hours a day, and so on. This provides "performance based analysis" that can reproduce critical circumstances.

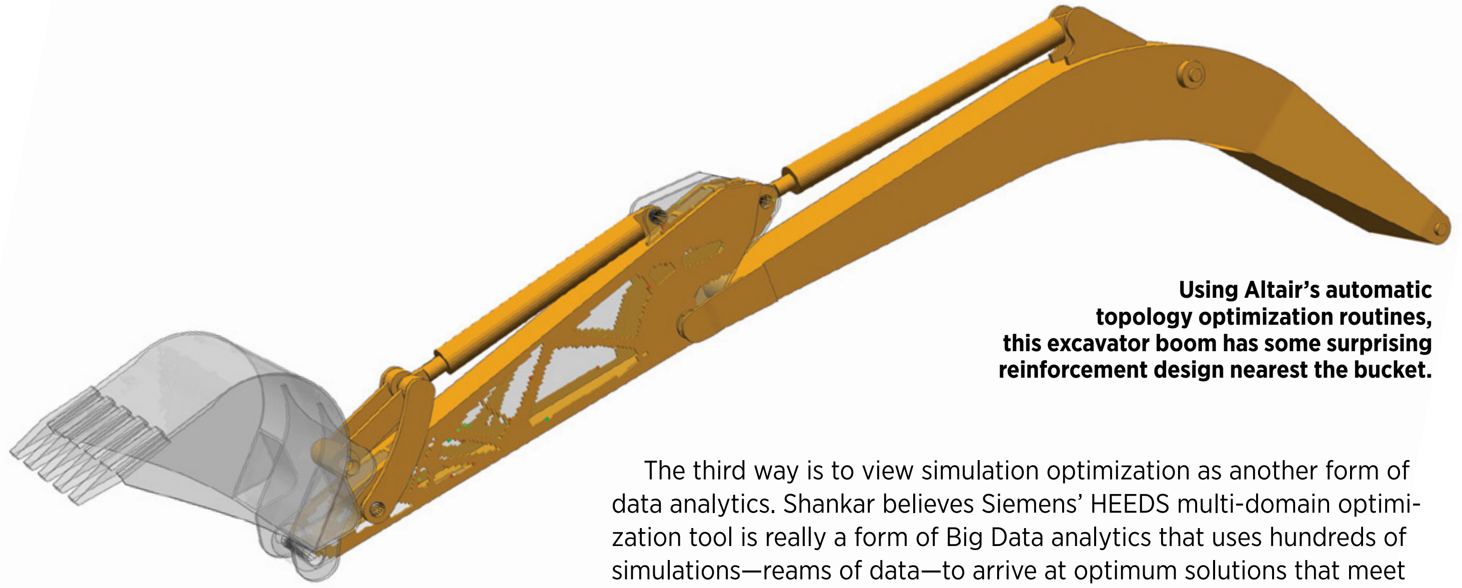
"Not only for a family of products, we can even get down to a particular serial number and determine how it is being used versus another individual product, continuously re-evaluating assumptions," explained Coronado. "Think of ThingWorx as the real-time aggregation engine of the real sensors to close the loop."

Holistic solutions

Ravi Shankar from **Siemens PLM Software** offers a comprehensive view of the problems off-highway equipment manufacturers face. Machines need to increase their effectiveness in terms of greater loads, but they also need to improve durability and fuel economy. Operator comfort is equally important.

"They need to ensure their operators are

With Big Data analytics coupled with a vision of vast data collection, whole product populations can now be incorporated into digital prototypes or digital twins. (PTC)



Using Altair's automatic topology optimization routines, this excavator boom has some surprising reinforcement design nearest the bucket.

not stressed too heavily to ensure smooth operation and efficiency," explained Shankar. "These requirements often work in conflict with each other, for example increasing load capacity means larger components that negatively affects emissions and fuel economy, as does air conditioning." These often force a look at different types of hybridization, including both electrical and hydraulic. These are more difficult to design than a pure mechanical system.

The solutions Siemens now offer are just as comprehensive and growing, expanding through acquisitions. To their existing tools in simulation and data management, they have added 1D and 3D systems simulations expertise through its acquisition of **LMS**, and CFD and design exploration through **CD-adapco**. Predictive analytics tools have come along with **Camstar** and its Omneo product.

Making sense of how simulation, IoT and predictive analytics all fit can seem confusing. "There are really three ways of thinking about Big Data and predictive analytics," he said.

First is integrating sensor-based data with physics-based simulations, using the digital twin concept. This means augmenting test and test data protocols with virtual sensors and bringing that data back into the early stages of design and engineering.

A second way is in the postprocessing of data, for instance by using its LMS Test.Lab technology. "For example, to use data from multiple sensors that measures durability for critical types of off-highway equipment," he said. Think of aftertreatment devices or critical joints. "There are reams and reams of such data, but you need to postprocess that data using math techniques and convert them to some key performance indicator useful in the design process."

The third way is to view simulation optimization as another form of data analytics. Shankar believes Siemens' HEEDS multi-domain optimization tool is really a form of Big Data analytics that uses hundreds of simulations—reams of data—to arrive at optimum solutions that meet given constraints. Multi-domain optimization, or MDO, combines the results of multiple simulation types, say engine, heat transfer, vehicle dynamics, into a single, results-oriented model. Sorting through the multiple, combined runs lets the software suggest the best solution that meets constraints.

"These are all valid ways of combining sensor data with physics-based simulations and test. Twenty years ago, some thought that CAE would replace test, but in some ways, test is just as important as CAE in the context of predictive analytics," he said.

Simulation and results

Makers of off-highway equipment rely heavily on classical proven methods of design and the company's legacy knowledgebase. These are viewed as reliable and dependable.

"Currently CAE simulation is becoming a more useful tool in a world dominated by traditional methods of equipment design," said Venugopal Ravula, Program Manager of **Altair**. "Many of the success stories we have had with heavy equipment companies have been in reducing weight and costs, and developing the methods to manufacture the biomimicry designs—large fabricated components."

The key to success in reducing weight and cost is in using CAE for optimization, according to Ravula. Design and topology optimization tools are premier components of Altair's software offerings. Across all industries, educating engineers in the proper use of optimization is needed.

"Often, customers do not know what they want," he said. "They might come to us through our consulting service asking about shape optimization, but once we expose them to other tools, like multi-domain optimization, they can see the benefits." He also stated that the industry is moving towards increasing use of MDO.

Topology optimization, where the shape of a component is suggested through automatic means, is one of Altair's specialties. A recent case study the company shared in an interview points to some of the peculiarities and advantages that future engineers need to know. Using its OptiStruct tool, Altair helped **Liebherr** redesign a crane boom that resulted in a component that was 20% lighter yet could lift 400 kg (880 lb) more. The resulting shape is not one that "tribal knowledge" or design books might produce, looking more organic with odd spacing of reinforcements. Other examples he showed included castings of tractor transmissions that reduced mass by 10%.

Ravula also notes that IoT, Big Data and data analytics are becoming more important in predictive maintenance, a field in which Altair also is active. ■

Lincoln unveils all-new, aluminum-bodied 2018 Navigator

Ford's **Lincoln** luxury-vehicle unit revealed the 2018 Navigator fullsize SUV at the 2017 New York auto show by touting its blend of smart basic engineering and smart features.

Like the recently-revealed Ford Expedition, its Lincoln counterpart is fitted with weight-saving aluminum bodywork to cut roughly 200 lb (91 kg) from the curb weight and help offset the mass of the new Navigator's copious luxury and advanced driver-assist features.

The new Navigator's single-spec powertrain is stark evidence that engine downsizing and advanced transmission technology have come fully of age: the body-on-frame Navigator, positioned to be one of the largest and most-spacious 3-row SUVs on the road, isn't deemed to require a V-8. Instead, Lincoln projects it will reap some 450 hp from a 3.5-L twin-turbocharged V6. And backing the thirsty 6-cylinder engine is Ford's new 10R80 10-speed automatic transmission.

At the 2018 Navigator's New York auto show launch, Ford had yet to distribute final specifications, but one company source said the new Navigator is expected to surpass the 17-mpg (13.8 L/100 km) combined fuel-economy rating of the previous-generation Navigator fitted with the twin-turbocharged V6 and all-wheel drive.

The 2018 Lincoln Navigator at its New York auto show premiere (image: Lincoln).

When specifications become final, Lincoln expects the 2018 Navigator to have class-leading cargo space and towing capacity (image: Lincoln).

Simplicity reigns for the Navigator's center console (image: Lincoln).

Although the new Navigator has Ford's latest weight-saving and powertrain know-how, the brand is steadfastly focused on the SUV's occupant-luxury and convenience attributes, as it must do marketplace battle with rival **GM**'s segment-defining Cadillac Escalade and fresh new European rivals that include large unibody SUVs from **Land Rover**'s **Range Rover** and **Mercedes-Benz**, among others.

The 2018 Navigator has a laminated windshield and side glazing and so-called Perfect Position seats for the front occupants that are 30-way adjustable and offer heating, cooling and massage. Twin 10-in (25-cm) screens on the back of the front seats allow second-row occupants to view separate video sources and the second-row occupants have their own dedicated climate-control sector. The third-row seats offer a power-recline function.

Other electronic features include a head-up display for the driver and Ford's clever Trailer Backup Assist that greatly simplifies the act of reversing a trailer. A simple pushbutton arrangement on the center console selects transmission gear (there is no "L," setting, however, so it appears it technically cannot be called a "PRNDL").

And one unique new function sees the adaptive LED headlights broaden their beam at low speeds to enhance peripheral lighting then narrowing the beams as speed rises to provide better long-range projection and reduce glare from signs and other roadside distractions.

Bill Visnic

Case unveils compact dozer loader concept at ConExpo

Called "Project Minotaur," the **Case** DL450 compact dozer loader is a "first-of-its-kind" machine that combines the footprint and performance of a compact track loader (CTL) with the power and dozing characteristics of a bulldozer. The crossover concept was revealed at ConExpo-Con/Agg 2017, where Case Construction Equipment conducted extensive focus groups with contractors to help determine how the machine can be further refined for production. The company would not confirm a launch date.

"Unlike concept vehicles that you see from other OEMs, which are simply meant to create a reaction, Project Minotaur is very practical evolution of two product lines that will provide added machine flexibility to those in the residential and commercial construction industries," Scott Harris, vice president – North America, Case Construction Equipment, said at the machine's reveal in Las Vegas. "It could also be a transformational piece of equipment for landscapers and other small to midsize contractors looking to add greater earthmoving power and precision to their operations."

The machine's platform runs all of the attachments a contractor might currently own for skid steers and CTLs.

"Contractors now have one machine on site that handles all of these items," Harris said.

C-Frame interface the core feature

How is this new machine different than a CTL matched with a dozer blade attachment? The answer is a new C-Frame dozer interface that pins directly into the chassis of the machine. This setup provides the stability and smooth operating plane of a CTL and ensures that operating power and stresses are channeled through the machine's chassis and not its loader arms.

The C-Frame, which is one of the more than 30 pending patents stemming from Case's Minotaur project, can be unpinned from the chassis and disconnected like any other attachment, allowing the machine to perform like a standard CTL.

"The problem with dozer attachments common with CTLs and skid steers—while effective in specific operations—is that they channel all operating stress through the coupler and the loader arms, and are really only suitable for ground-line work," said John Dotto, brand marketing manager, Case Construction Equipment. "This affects performance and adds wear and stress to those components. The operator gets true dozing performance with this machine—no arm float, a consistent plane and true 6-way blade performance through the machine's new controls."

Counterweight has been added to the machine and the undercarriage features steel tracks and grousers "for added bite and pushing force," Harris said. Other enhancements include a fifth roller for better traction—compared to the standard four on a CTL—and greater ground clearance, at 13 in (33 cm), to reduce the likelihood of drag.

A rear ripper assembly increases functionality without sacrificing access to daily-service points.

Proven frame, with some tweaks

"Project Minotaur" was conceived between the Case skid steer manufacturing plant in Wichita, KS, and **CNH Industrial**'s research and development center in Burr Ridge, IL.

"It's a project that's more or less bridged the gap between last ConExpo [in 2014] and here. It's been in development for a couple years," Dotto told *Mobility Engineering*. "The task was given to the engineering group to find a solution for that contractor that's using a large track loader to do a lot of earthmoving and pushing. So it started as a brainstorming project in the Wichita design and engineering group."

The DL450 combines current and

The Case DL450 machine concept marries the current TV380 compact tractor style frame with a radial-lift loader arm design similar to the Case legacy 465 skid steer.

The cab and controls inside the machine are similar to what's in current CTLs and skid steers—*and* dozers. Some of the pending patents involve the changeover from CTL operation to dozer.

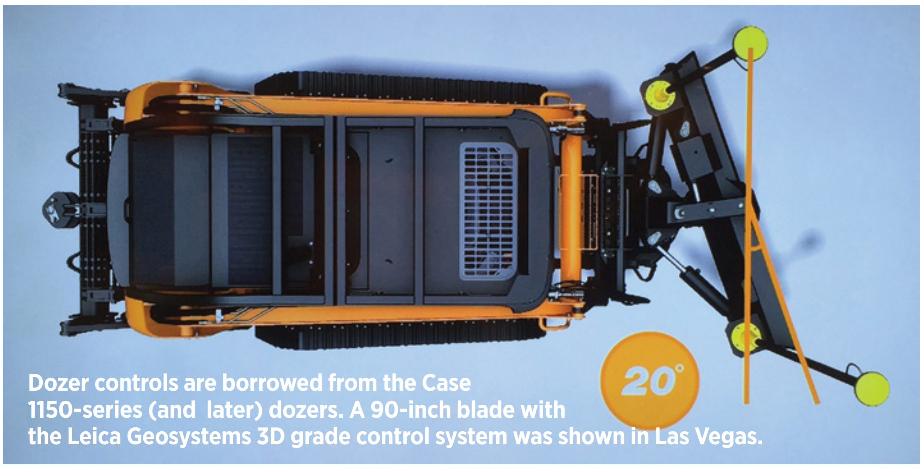
legacy technologies and designs to create a new product category, Harris said. The frame of the machine is similar to that of a current TV380 compact tractor, the largest and most powerful CTL in the Case family, but has been further increased in size to handle greater loads.

The frame is based on a vertical-lift machine, but "Case engineers wanted to build the pushing power and the frame strength of a radial-lift machine into the design, so the machine marries that TV380-style frame with a radial-lift loader arm design similar to the Case legacy 465 skid steer," Harris said.

Another inspiration for this concept machine was the 450 Series Case dozers, according to Dotto. "Our engineers focused on building performance and operating characteristics similar to that platform into this machine. Early indications show that they've accomplished this, with an anticipated drawbar pull of around 21,000 lb," he said.

A rear ripper assembly increases functionality without sacrificing access to daily-service points. (Photo by Ryan Gehm)

The core feature is a new C-Frame dozer interface that pins directly into the chassis of the machine. This setup ensures that operating power and stresses are channeled through the machine's chassis and not its loader arms. (Photo by Ryan Gehm)



Dozer controls are borrowed from the Case 1150-series (and later) dozers. A 90-inch blade with the Leica Geosystems 3D grade control system was shown in Las Vegas.

Cab and controls

The cab and controls inside the machine are similar to what's in current CTLs and skid steers—and dozers. Similar to ISO controls, forward and reverse travel and steering is controlled with the left hand. Boom and bucket controls are manipulated with the right. Those same controls in the right hand control the lift angle and tilt of the 6-way dozer blade.

At least one of the pending patents involves the changeover from CTL operation to dozer. "Where you'd normally see an ISO/H-pattern changeover switch in a CTL, you're going to see an ISO-to-dozer control switch on the DL450," Dotto said.

"If you have standard CTL sticks in there, you're not quite dozing because you don't have all the six-way ability," he continued. "So that's why we threw in the dozer-style controls. The dozer controls that we're using are from our 1150 and up series dozers, a 90-inch blade with the **Leica Geosystems** 3D grade control system."

Dozer control features such as blade shake and pitch adjustment will be incorporated. Focus groups also will help determine "what the future brings for Project Minotaur with grade-control options," Dotto said.

"We see this [new machine] as something that will help contractors achieve ideal utilization rates and simplify the footprint of equipment they deploy to a site," he said.

Ryan Gehm

Dodge puts 375-hp Hemi V8 in Durango SRT

"Performance" SUVs are not a new concept, but **FCA**'s Dodge brand opens a new niche-within-a-niche with the unveiling of the 2018 Durango SRT at the 2017 Chicago auto show, calling it "the fastest SUV in its class."

Dodge officials didn't directly say just who's asking for a grocery-getter SUV with 475 hp (354 kW) and 470 lb·ft (637 N·m) from a 6.4-L (or, more historically relevant, 392-in^3) V8 that enables cutting a 12.9-s quarter mile time, but the Durango SRT will be in showrooms for that buyer starting in the fourth quarter. Some of the work of adapting the 6.4-L Hemi for the Durango already was done: it is the same iron-block, pushrod V8 with a 10.9:1 compression ratio that appears in the Jeep Grand Cherokee SRT, which shares its architecture with the Durango.

The new Durango SRT gets its share of special engineering, though: Dodge said the standard 8-speed **ZF** automatic transmission has specifically-tailored shift points and when driven in Sport mode, shift times are cut by up to 50%. Using Sport mode also commands the all-wheel-drive's single-speed electronic transfer case to apportion 65% of drive torque to the rear axle. Change to Track mode and up to 70% of drive torque can be sent to the rear axle, while transmission shift times are cut to 160 ms.

The 2018 Dodge Durango SRT packs a 6.4-L V8, extensive chassis and driveline upgrades and widened bodywork to back up its performance message (Image: Bill Visnic).

Durango SRT interior features a variety of performance- and luxury-oriented changes, including a flat-bottom steering wheel and 180-mph speedometer. (Image: FCA)

The 6.4-L iron-block OHV V8 generates 475 hp from a 10.9:1 compression ratio. (Image: FCA)

A new-design T-shift handle couples with steering-wheel paddles to encourage manual sequential gearshifting and the Sport shift mode can be used without any change to suspension, stability-control or drive-split parameters.

Dodge said the Durango SRT's suspension—a short-long-arm arrangement in front and an independent multilink at the rear—uses specially-tuned adaptive dampers supplied by **Bilstein** and has 3% stiffer front springs, 16% stiffer rear springs and an 18% stiffer rear anti-sway bar. The entire setup's reactions are controlled through a seven-position drive mode selector that includes snow, towing and valet settings. Brakes are upgraded at each corner with **Brembo** six-piston front and four-piston calipers gripping 15-in slotted front rotors and 13.8-in rear slotted rotors.

Riding on the same 119.8-in (3043-mm) wheelbase as conventional Durangos, the SRT has widened bodywork to accompany the go-fast hardware, while a functional cold-air intake and heat extractors serve to reduce intake-air temperatures by up to 18°, Dodge claims. Apart from the obvious exterior differentiation from standard-issue Durangos, the SRT model also includes special AWD badging and even "392" badges to pay homage to the engine's displacement in "cubes."

Pricing for the Durango SRT was not detailed, but in keeping with the SRT unit's practice, all buyers of the Durango SRT are entitled to a one-day performance-driving course at the **Bob Bondurant School of High-Performance Driving** in Chandler, AZ.

Bill Visnic

Work trucks strive to curtail addiction to fuel

Fuso's fully electric eCanter is a Class 4 truck with a range of 100 miles.

Reducing fuel consumption was a focal point of several trucks unveiled in March. Electric drivetrains and four-cylinder engines were among the tactics disclosed at The Work Truck Show in Indianapolis.

Mitsubishi Fuso Truck of America, Inc. rolled out an all-electric medium-duty work truck, the eCanter, which it says will be the first plug-in electric work truck produced by a major truck manufacturer. The Class 4 truck has a payload capacity of roughly 9380 lb (4255 kg).

It offers a range of up to 100 mi (160 km), one-hour quick charging, and standard eight-hour overnight charge. Compared to a two-year lease, the eCanter will carry a 15-20% premium over a comparable diesel engine, Fuso CEO Jecka Glasman said. She added that it weighs about 800 lb (363 kg) more than a similar diesel vehicle.

"There are six batteries developed by **Mercedes**, they output 360 V," said Otto Schmid, Fuso's Director, Product Management. "They provide 82 kW·h of energy to power a 129-kW asynchronous motor. These motors have high torque—compared to a V10 gasoline engine, they provide 34 foot-pounds more torque."

Ford took a different tack on electrification, expanding its Advanced Fuel Qualified Vehicle Modifier program to include three developers that install electrified and hydraulic hybrid powertrains on Ford trucks and vans. **XL Hybrids**, **Motiv Power Systems** and **Lightning Hybrids** offer solutions for a range of Ford vehicles popular with fleet and commercial customers, including F-150, F-250 to F-550 Super Duty, F-650 and F-750 medium-duty trucks, Transit and E-Series vans and chassis, and F-53/F-59 stripped chassis.

One supplier noted that fleets are now upfitted to hybrids solely to save money.

"The days of buying hybrids just to be green are over," said Clay Siegert, chief operating officer of XL Hybrids. "Every acquisition now is based on a financial payback."

A four-cylinder engine was the highlight of **Isuzu** Commercial Truck of America's 2018 FTR, a Class 6 medium-duty truck, which the company says is the first four-cylinder in this segment. It's powered by the Isuzu 4HK1-TC 5.2-L turbocharged diesel. Isuzu didn't provide mileage data, but said the turbocharged 4HK1-TC generates 520 lb·ft (705 N·m) of torque at 1650 rpm and 215 hp (160 kW) at 2500 rpm.

The FTR employs an **Allison** 2550 RDS six-speed automatic transmission with power take-off (PTO) capability. The front axle has a capacity of 12,000 lb (5445 kg), while the rear axle's capacity is 19,000 lb (8620 kg).

In another change, Fuso unveiled a gasoline powertrain for its FE Series medium-duty cabover trucks. A 297-hp (222-kW) V8, the 6-L PSI-GMPT Vortec, powers three Fuso models, the FE130, FE160 and FE180, spanning Class 3, 4 and 5. An Allison 1000 6-speed automatic transmission will offer a PTO capability. Fuso also focused on safety, teaming up with **Mobileye**, using its advanced collision-avoidance system, which is used on a number of passenger cars.

"We did a test, installing the systems and letting people drive for one month without turning them on," Glasman said. "When the Mobileye system was turned on, emergency braking and lane departure without warning were reduced by 50%."

Terry Costlow

Four-cylinder engines help Isuzu's FTR family conserve fuel.

Early ride: Lucid Motors' 1000-hp Air 'alpha' prototype

Prototype of Lucid Motors' Air electric luxury sedan, camouflaged in the Las Vegas early evening. (Image: Bill Visnic)

Always an early test for the veracity and viability of automotive startups: Have you got a car that runs?

Menlo Park, California's **Lucid Motors**, has at least one. We know because its chief technology officer, Peter Rawlinson, took us for a ride.

Lucid is the electric-vehicle startup that's had the good fortune to often be named as the most viable competitor to **Tesla** and the bad luck to be forming at time when at least one other venture capital-intensive EV startup has been hogging the headlines with its financial straits. But Lucid has attracted a number of seasoned industry engineers and developers (including from Tesla) and appears, at least to equally seasoned media, to be achieving legitimate development goals and advancing on a realistic timeline.

So Lucid came to Las Vegas during the recent Consumer Electronics Show (CES) to make its own positive headlines. That goal centers mostly on the fact there's an actual car in which to ride. Rawlinson will drive the probably almost-priceless mule, an early "alpha" prototype, he says. There's barely any interior, the thing wears creative camouflage—although Lucid has provided plenty of images of the production Air's projected appearance—but the doors work and there are even real (if rudimentary) seats.

Air prototype's interior: large, vivid data screens and some necessary components borrowed from more prosaic production models (Image: Bill Visnic).

Rendering of the production version of the Air sedan, slated for showrooms—of some sort—in 2018 (Image: Lucid Motors).

Not 1000 hp—yet

Lucid claims 1000 hp for the Air, but we can't say the prototype felt like 1000 hp. First, because Rawlinson made it clear this development-mule's driveline was dialed back from the output stated for a production version and, equally important, we wouldn't know what 1000 hp is supposed to "feel" like, anyway—we've been in neither a Bugatti Veyron or a World of Outlaws sprinter.

Nonetheless, it's clear this "alpha" prototype of the Air has an energetic power-to-weight ratio. Despite its probably curb weight in the 4400-lb (2000 kg) range that includes the undisclosed but undoubtedly substantial weight of the lithium-ion battery pack being co-developed with **Samsung SDI** (its optimized packaging is claimed to be one of the secrets to the Air's extreme range capability), when Rawlinson toes the go-pedal, the car lunges assertively. We don't wind up this prototype to the kind of speed that might give clearer indication of its raw power, but the car shoulders blithely past some traffic that isn't exactly puttering, evidencing mid-range thrust that certainly seems to rival some of the forced-induction V6s and V8s we've recently tried.

Low-roller

What's more revealing about the Air prototype—at least in terms of what it might suggest about this platform and propulsion package—is the pancake-flat cornering behavior. Rawlinson does what he can to upset the chassis with sharp and abrupt steering inputs or fully unstick it with too much cornering speed. This Air "mule" is having none of it: there's an uncanny lack of body roll and it refuses to slide, even when brazenly provoked to do so.

The low degree of body roll should well serve the Air's luxury-car positioning, as will its seeming refusal to slide, although this behavior may not win many of the budding Lewis Hamiltons of potential owners.

We remark on this and the generally firm—but hardly rocky—ride quality and Rawlinson is quick to remind this prototype also is riding on quite fundamental suspension tuning, a setup that's likely to be far from the final-production state. Will that mean more body roll as a tradeoff for a softer state of primary tune?

Finally, there's not much to say about an interior of a prototype, even a luxury one, but we do try the backseat to test Lucid's claim of a uncannily voluminous rear-seat experience. It's genuinely grand back there: the flat floor definitely contributes. Relax against what will be reclining rear seatbacks in the production Air and you'll need one of those reach-the-top-shelf claw sticks to touch the back of the front seat. It's pretty clear there's more room back there than in most conventional full-size sedans, regardless of whether the interior ends up with those thin and svelte seats Lucid's shown in its press images.

Was the Air prototype rough and creaky and full of gear whine? Sure was. That wasn't the intended takeaway, of course. Lucid's prototype is thrusty and flat-cornering and its CTO wasn't afraid it would break while hammering it around the streets of Vegas. That moves the needle on the credibility scale—the real goal for today's startup EV automaker breed. What we've seen so far is convincing.

Bill Visnic

Renault claims Chevy Bolt-beating range for new Zoe EV

LG Chem's new Z.E.40 battery delivers a claimed 41 kW·h. The pack has 192 cells and 12 modules.

When switching on a pure electric car, the first thing any sensible driver will do is check the remaining estimated battery range. The figure displayed is often likely to create varying degrees of anxiety and/or trigger some mental arithmetic. But **Renault**'s message is all about confidence as it launches the latest hatchback 4-seat, 5-door Zoe R90 supermini EV.

Featuring a new **LG Chem** lithium-ion battery that delivers significantly greater energy density than used previously, the new R90 electric is expected to deliver just over 400 km (249 mi) on the NEDC (New European Driving Cycle), with an 'honest figure' of 300 km (186 mi) and a "worst case winter" range (with lights, heater and wipers on full blast) of 200 km (124 mi).

If those claims by Renault are validated, the new Zoe will offer the longest range outside of **Tesla** and will beat the current non-luxury EV champ, the 2017 **Chevrolet** Bolt EV. The Bolt carries an EPA rating of 238 mi (383 km) and Bolt owners in southern California have squeezed over 300 mi (483 km) range on a single charge.

LG Chem's new Z.E.40 battery delivers a claimed 41 kW·h. Assembled at Renault's Flins, France facility, the Z.E. 40 pack has 192 cells and 12 modules. The increase in output to 41 kW·h—claimed as the highest energy density EV battery currently in production—was achieved through revised chemistry and adding "active materials," state company engineers.

Renault has applied for 95 patents on the Zoe traction motor, which is rated at 220 N·m and 68 kW. The car is claimed to accelerate to 100 km/h (62 mph) in 13.5 s and can reach a top speed of 135 km/h (84 mph). Curb weight is 1468 kg (3236 lb). On the road, the car's power feels adequate, as judged by the author in a test drive, but it does not have the snappy tip-in that some EVs provide.

The Zoe is fitted with a heat pump as standard, which uses about three times less energy than a regular HVAC system for an equivalent level of heating, claims Renault. The car has an Eco mode said to enhance range by around 10%.

Renault derives its road EV technology from the company's involvement in e-motorsport. The e-dams team, highly successful in the **FIA** Formula E Championship, is managed by four times F1 World Champion Alain Prost and e-dams founder, Jean-Paul Driot.

The test program for the Zoe includes experiencing -20°C in Sweden to check battery performance. The car was also driven through 40 cm (16 in) of water at 10 km/h (6.2 mph), totally immersing the battery.

Stuart Birch

New Lexus LC brings new platform, hybrid system

For Chief Engineer Koji Sato, the greatest engineering achievement on the 2018 **Lexus** LC is the coupe's sharp and refined driving dynamics.

To help achieve that crisp performance, engineers focused on finding the ideal inertia specifications, including a low center of gravity that's close to the driver's H-point. They designed the LC's body structure with the highest torsional stiffness of any Lexus and they developed a new suspension design.

"We had to be creative with the suspension architecture so the suspension tower height would be kept low while still being able to house large 21-in wheels," Sato explained. "We also focused on the design and suspension pick up points to not only lower the height but also to enhance the rigidity.

"So we applied a multi-link suspension," he said. "It took six months to find the best geometry of the suspension arms." Veteran **Toyota** engineer Sato and Lexus product experts spoke with *Mobility Engineering* during a February media preview of the all-new LC 500 and the hybrid LC 500h on the Big Island of Hawai'i.

Riding on a 113-in/2870-mm wheelbase, the new Lexus LC benefits from extensive underbody CFD analysis and development.

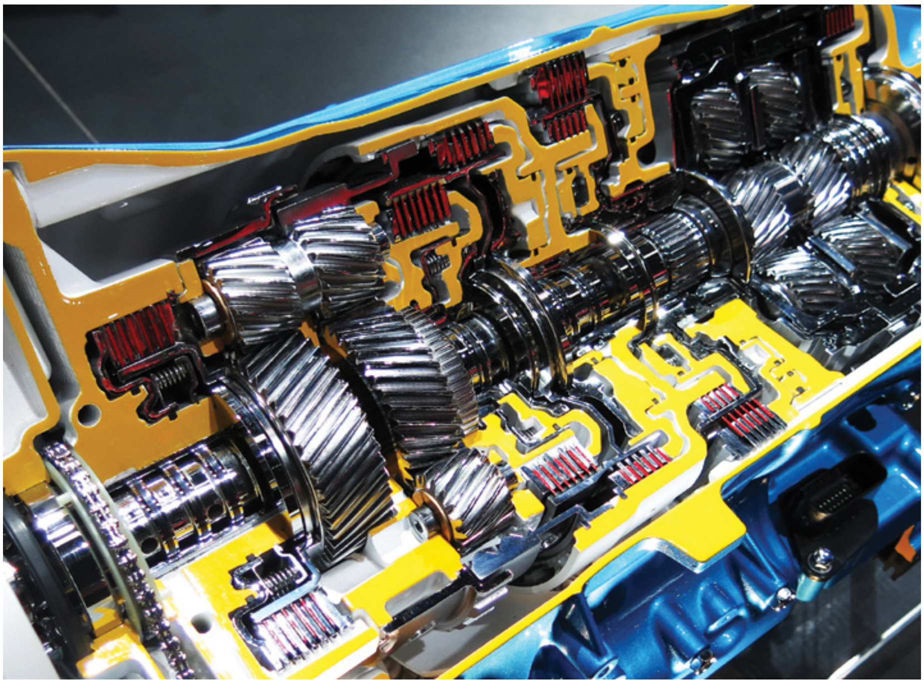
Lightweight materials mix

Both versions of the visually captivating LC coupe debut Toyota's GA-L (Global Architecture-Luxury) front engine/rear drive platform for high-performance/luxury models, for global markets. The car's design is exceedingly close to the LF-LC concept shown at the 2012 Detroit auto show. But what's unseen is equally intriguing. The coupe's underbody went through extensive CFD simulation and wind tunnel testing for downforce and diffuser design evaluations.

"We needed to create suitable airflow in correlation to the air pressure being produced from the upper body towards the rear of the vehicle," Sato explained. "The underbody is obviously covered to have optimum airflow. We also have created an air duct in the front part of the rear wheel to reduce turbulent air flowing through the door side panels as well as the wheel housing."

The 113-in (2870-mm) wheelbase LC rides on run-flat tires supplied by **Bridgestone**, **Dunlop** and **Michelin**. Eliminating the need for a spare tire provided trunk space for the auxiliary battery and weight savings. LC's 4280-lb/1935-kg curb weight (4435-lb/2012-kg for hybrid version) derives from a mix of lightweight materials.

Front fenders, hood, and side door panels are aluminum. The die-cast aluminum front suspension towers were joined to steel via self-piercing rivets, a Lexus first. Carbon fiber reinforced plastic (CFRP) is used in the inner door panels and trunk lid. And a CFRP roof is available with the performance package, which also adds an active rear spoiler. The platform extensively uses ultra-high-tensile steel.



The Aisin-engineered-and-sourced AWR10L65 10-speed planetary automatic is used in the new LC coupes. (Lindsay Brooke photo)

Aisin 10-speed, new Hybrid system

The normally aspired Toyota 5.0-L gasoline V8 delivers a rated 471 hp (351 kW) at 7100 rpm and 398 lb·ft (539 N·m) at 4800 rpm. This engine is based off that used in the Lexus RC F sports coupe and the GS F sedan. "The intake/exhaust valve design and layout as well as the exhaust pipe configuration is newly developed for the LC," noted Sato, and the ECU is remapped. A sound generator fine-tunes the V8's intake noise that is piped to the cabin.

The V8 mates to **Aisin**'s new Direct Shift 10-speed planetary automatic with a full range lock-up control torque converter. "By having 10 gear sets to work with, it allowed for a quiet and comfortable drive at higher cruising speed, while still being able to enjoy a wide range of gearshifts through acceleration and deceleration," Sato explained.

The transmission's AI-SHIFT control, a Lexus first application, selects the optimum gear based on vehicle speed, accelerator use and via an estimation of the driver's preferences/intentions. LC is the first in its segment with a 10-speed automatic, with 8- and 9-speed units predominating.

LC 500h debuts Lexus' first Multi Stage Hybrid System. Unlike a conventional full hybrid powertrain in which engine output is amplified by an electric motor's reduction gear, the multi-stage system amplifies the electric motor via the automatic transmission.

The multi-stage shift device changes the output in four stages: first/second/third simulated gears to match the first mechanical gear; fourth/fifth/sixth virtual gears to match the second mechanical gear; seventh/eighth/ninth simulated gears to match the third mechanical gear; and an overdrive virtual gear ratio to match the fourth mechanical gear.

LC can be outfitted in 20-in cast aluminum wheels, or the optional 20-in and 21-in forged aluminum alloy wheels.

According to Bill Kwong, a Lexus College technical expert, "The multi-stage aspect is akin to a transfer case or an automatic differential." The LC hybrid driver can opt for manual gear selection using the steering-wheel-mounted magnesium alloy paddle shifters that provide a Lexus hybrid-first 'manual-hold' feature.

LC Chief Engineer Koji Sato was involved in the process of developing a new seat design that underwent 50 test cycles.

LC 500h uses a 3.5-L gasoline V6, similar to the current RX 450h crossover vehicle. It's rated at 295 hp (219 kW) at 6600 rpm and 256 lb·ft (347 N·m) at 4900 rpm. The "dual injection" system uses both direct and port injectors, with variable valve timing with intelligence wide (VVT-iW) on the intake and VVT-i on the exhaust.

"The previous hybrid system could only go into Atkinson cycle," Kwong said. "But now with both Atkinson cycle and auto-cycle, it's possible to have wide, broad cam-phasing." This new hybrid system essentially responds to driver inputs without a lag between rpm and vehicle speed.

There are two permanent-magnet synchronous motors on the LC hybrid. The primary generator (Motor Generator 1/MG1) handles engine start and controls engine speed. Motor Generator 2 (MG2) drives the rear wheels and handles regenerative braking. Positioned between the rear seats and the luggage compartment are 84 lithium-ion cells producing 310.8 V. This Li-ion battery pack, a first for a Lexus vehicle, is 20% smaller than the NiMh pack in the Lexus LS.

The LC 500 and 500h will be sold globally with U.S. sales beginning in spring 2017.

"We're forecasting that the sales split will be 90% for the LC 500 and 10% for the LC 500h," said Brian Bolain, Lexus' General Manager Product & Consumer Marketing. The U.S. price for LC 500 is $92,000 and $96,510 for the LC 500h.

Kami Buchholz

COMPANIES MENTIONED

AD INDEX

IQM's Dan Lawrence sees considerable cross-industry interest in flexible hybrid electronics. (Lindsay Brooke photo)

A wiring harness on film?

Imagine your next-generation vehicle wiring harness printed in electrically-conductive ink on a thin, stretchable and flexible molded substrate with embedded sensors. Known as flexible hybrid electronics (FHE), this technology uses a combination of high-precision printing technology and advanced electronics. The result is lightweight, package-efficient and physically flexible circuitry, first used by **Ford** on a limited trial basis in the overhead console of the 2013 Fusion.

"FHE is basically printing the circuits on a large roll of film," explained Dan Lawrence, program manager at the **IQM Research Institute**, an advanced-technology incubator that is promoting FHE within multiple industry sectors. He noted that FHE can be "incorporated into any substrate—an injection-molded door inner panel or the physical structure of the vehicle." Headliners, the centerstack HMI, the roof panel incorporating photovoltaics and RFID antenna, to name a few applications.

Mobility Engineering spoke with Lawrence at IQM's Ann Arbor, MI, offices.

Was the impetus behind FHE vehicle electrification, connected-car and autonomy trends?

Yes, all of them. Because it allows you to do things that incumbent harness technology can't. And every kilogram you can shave off a car has tangible fuel economy benefits. The military land-vehicle systems folks at **U.S. Army TARDEC** and the commercial-appliances sectors are also interested. We're working with companies across the industry. It's up to them to take those learnings and apply them to their own projects for commercialization.

We're not looking at vehicle programs 15 years down the road—we're looking at the next 2 to 5 years. FHE is a platform that's basically ready now. We're also looking to add some laboratory and demonstration capability to this area as well, including prototyping and small-scale batches of actual products. We're (IQM) here to evangelize and collect the industry's wants and needs and show what's possible so that the designers, engineers, purchasing departments can say, 'Hey, this has value, let's bring this technology forward.'

The technology would be a disruptor to incumbent harness technologies supplied by the Yazakis and Delphis of the world, yes?

FHE can be a distruptive technology because the wire harness manufacturer, the headliner manufacturer and whomever else is in the supply chain up to the OEMs, in the sense that it has potential to add value. If you're only making headliners, FHE offers the chance to make them far more functional. We're not here to steal anyone's business; we're here to help them grow.

How does FHE incorporate electronics hardware such as circuit boards?

Circuit boards will remain with us for the forseeable future, but in terms of manufacturing they're rate-limited by pick-and-place machines. FHE is basically printing the circuits off a large roll of film. My background's in the printing industry—it's amazing how fast and in what large volumes the product comes off the press. Being physically flexible in and of itself is not really the selling point—it's where you can put that flexibility, including package and manufacturing flexibility. A key benefit is we can make hundreds of thousands and also do customized ones. We use high-speed production and a change of printing plates won't break the bank.

You can use an entire door panel as electronics, for example. You can't do that with a printed circuit board. Or for any user interface. On an appliance control panel, if you have a hard circuit board and have your switches populated and your lighting populated, it starts to get pretty expensive. We'll probably still need some microcontrollers depending on the design rules, but going forward we'll need less and less of them.

Does the ink contain a magnetic constituent?

You can have magnetized ink for a coil and dielectric ink for a capacitor and semi-conducting ink for a transistor. If you disassembled your laptop and looked at its board, a decent amount of the content can be replicated with the printing process.

For more information on FHE, contact Dan Lawrence at: dan.lawrence@iqmri.org. Also see www.manufacturing.gov.

Lindsay Brooke

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