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AUTOMOTIVE, AEROSPACE, OFF-HIGHWAY

A quarterly publication of SAE International and SAE India

FORMULA E

Preview: electric vehicle racing series

SMACing the automotive industry
Connectivity meets social, mobile, analytics, and cloud

The 3i paradigm
Ideation, incubation, and implementation in Indian industry

Automotive electronics
Infotainment looks toward virtualization

Volume 1, Issue 4

September 2014

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Mahindra Racing will be contesting the new Formula E racing series, which starting this month will travel the world with its electric racecars to encourage racing fans to think differently about the technologies they use.

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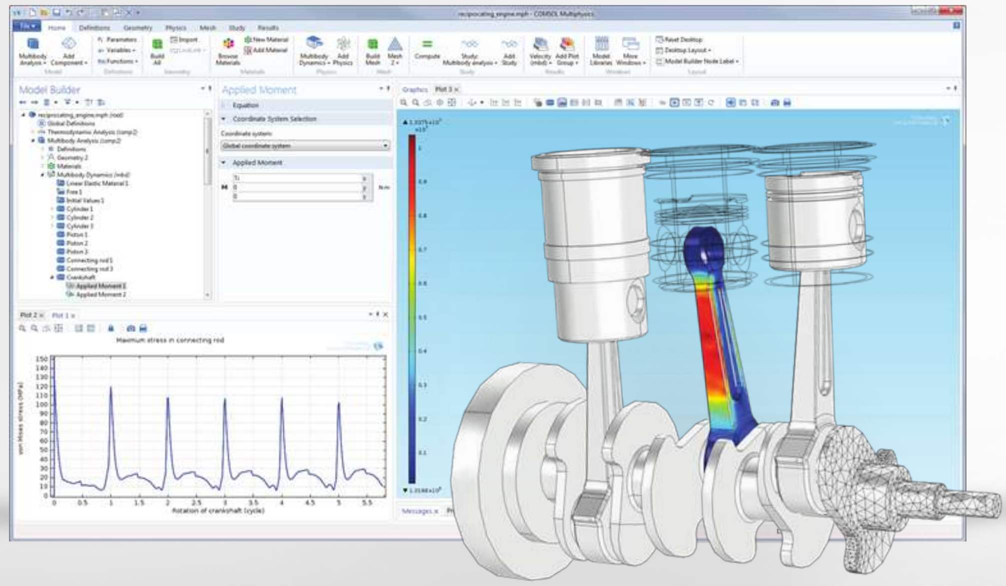

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EDITORIAL

Racing to production

The world's automakers are increasingly pushing for their racing efforts to be more relevant to consumers and to more closely mirror the production vehicles they want to sell.

A case in point is covered in our special racing-focused cover story in this issue. In "A new formula for racing" beginning on page 44, we take a look at the new Formula E electric racecar series, which showcases electric propulsion technology and encourages fans to think differently about the technologies they use. **Mahindra** Racing is the eighth and only Indian team to race in Formula E.

The series' season will commence this month on September 13th with a race in Beijing and conclude June 27th in London. In between, the series will visit Putrajaya, Malaysia; Rio de Janeiro; Punta del Esta, Uruguay; Buenos Aires; Los Angeles; Miami; Monte Carlo; and Berlin. All of these will be conducted on city streets rather than on dedicated circuits to emphasize the connection with production cars.

Because racing EVs struggle with the same issue of battery capacity as conventional EVs, the series will start with 1-hour races. Even that is too long for today's batteries when driven at race pace, so drivers will pit midway through the race and jump into a waiting fully charged car to continue.

SAE International and **SAEINDIA** are also playing roles in making racing more relevant to production vehicles through student competitions, but in a different way—by providing the venue to help train the next generation of top vehicle engineers.

At the high-profile 2014 Formula SAE Michigan event in May, **Oregon State University**'s Global Formula Racing (GFR) team took top honors in the open-wheel racecar competition, followed by **Technical University of Munich** and **Universitat Stuttgart**. Over the course of four days, the Formula SAE teams' vehicles, powered by 600-cc four-cylinder and 450-cc single-cylinder engines from **Honda**, **Kawasaki**, **Suzuki**, and **Yamaha**, were judged in a series of static and dynamic events including technical inspection, cost, presentation, and engineering design, solo performance trials, and high-performance track endurance runs.

At Formula SAE's sister event in India, SUPRA SAEINDIA 2014 held in July at MMRT (Madras Motor Race Track) Chennai, engineering students from colleges all over India formed 85 teams to create a virtual design, build a prototype, and test their own Formula-type racecar. The Camber Racing team from **SRM University** won this year's event, followed by Team Octane Racing of **College of Engineering, Pune** and Ojaswat from **Chandubhai S. Patel Institute of Technology**.

The event is sponsored by **Maruti Suzuki India** Limited as the title sponsor and supported by **Rajalakshmi Group of Institutions**, Chennai. Other sponsors include **Continental Automotive**, **Bharat Petroleum** Corp, Ltd., **Bosch**, **Altair**, **Ansys**, **Eaton**, **Indian Oil** Corp. Ltd., **Arai**, **Victora Tool**, and **Roots**.

"In this process, students learn to develop a design, understand the process of new product development, industrial procurement, manufacturing, assembly, and prototyping," said Dr. S. Thirumalini, Convener, SUPRA SAEINDIA 2014. "The objective of this event is to bring out the latent talent of students so that it fulfills the Automotive Mission Plan (AMP 2016), the focus to make India an international automotive hub."

A major driver for the popularity of the collegiate student competitions is the demand for their "graduates." In the U.S. and India, and around the world, these programs are renowned for producing top engineering graduates because the competition provides a real-life engineering education experience including project management.

"Students realize their talent through such an experience, making them proven candidates for the future as technocrats, entrepreneurs, designers, innovators, and leaders," said Mr. Asit K Barma, Chairman, Media, Communications, Publications Board, SAEINDIA.

The experience gained designing competition vehicles is extremely valuable to the students. Ultimately, the industry also benefits in having access to more prepared engineering recruits for the production of better-performing vehicles of the future.

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FOCUS

Change for the better

SAEINDIA is in the midst of changes, with the new team firmly in place focusing on objectives set for the year, and the country witnessing a change of government in a smooth transition involving 1.2 billion people. The new government has placed the right emphasis on all-round growth, with an accent on the automotive industry, as it employs a huge workforce and is directly linked to the surge in the economy. It is also encouraging FDI (foreign direct investment) in more sectors including infrastructure and mobility, which should impart an added impetus to the sagging spirit of the commercial vehicle and off-highway in-

Dr. Aravind Bharadwaj
President, SAEINDIA

dustries. There are definite pointers to positive growth in the passenger-vehicle segment, with the off take registering an increase in the past two months after negative growth for over a year.

SUPRA SAEINDIA, the Formula car design competition, was completed with great acclaim from industry and institutions. The fact that 81 teams made up of more than 2000 students were involved in the dynamic track competitions shows the huge popularity of the event and demonstrates the ingenuity of the Indian engineering students to design and develop a Formula car for competing with the best in the country.

All the three verticals had planned programs during the visit of 2014 **SAE International** President Daniel Hancock during July, with the Off-Highway Board having a one-day workshop on "Futuristic Technologies and Orbit Shifting Business Strategies for Indian Off-Highway Industry" on the 22nd at Pune, followed by the Aerospace Board having a conference jointly with **Project Management Institute** of India on July 24, and the Automotive Board planning a Blue Ribbon CEO Conclave on July 25 at Chennai. Each of the events was a new benchmark in addressing the needs and concerns of mobility professionals.

We had the first successful International Lecture for the year, with Dr. William Mark McVea conducting a course on Modern Vehicle Transmissions, which received robust support from major OEMs and Tier 1 and 2 suppliers. The feedback was positive and encouraging and should help us to organize more such courses from international experts at different locations serving the objective of knowledge enrichment and dissemination.

The Aerospace Board is planning a program on IVHM (Integrated Vehicle Health Management) of Aircraft during October 2014, and experts from Europe and the U.S. have been invited to participate in the event with the incoming President of SAE International also likely to join us during the conference. This will be organized for the first time in India by SAEINDIA and can be a trendsetter for the future.

The Automotive Board is also planning to conduct an event for two- and three-wheelers for the first time in India as there is massive technical manpower in the industry that can involve and contribute to growth in the SAEINDIA talent pool and professional membership.

The SAEINDIA Southern Section is organizing a Knowledge Round Table with **Mahindra**, **Renault-Nissan Alliance**, and **WABCO** and will rally members to form a community of professionals to discuss, learn, brainstorm, and practice with greater involvement and mutual exchange of ideas and thoughts.

We have other plans and programs under the Professional Development Board and Meetings & Exposition Board that will add a new dimension to our activities and offer a great value proposition to professional members.

We are determined to make a difference with value addition for members so that they can look forward to pleasant engagement in SAEINDIA activities.

SAEINDIA News

Blue Ribbon CEO Conclave addresses 'Business Practices for Next-Generation Mobility'

Dr. Arun Jaura: "Holistic deployment for next-generation mobility will require agility, collaborative style of decision making, and a mind-set change to proactively leverage innovative cross-industry practices."

Daniel M. Hancock: "Collaborative Innovation is a lever that will catalyze next-generation business practices. Nurturing student initiatives along with supporting resources will build the appropriate pipeline for injecting fresh ideas in the mobility fraternity."

In India, like many other emerging nations, the projected growth in urban development is coupled with the challenge of providing and managing movement of people and goods in inner cities. For businesses, this is a huge opportunity to integrate and deploy smart solutions to ease congestion, enhance safety, and ensure efficient energy management for CO_2 reduction. A holistic deployment will require agility and a mind-set change to proactively review the current state of the union. With the Prime Minister of India's focus on Smart Cities, next-generation mobility and business practices become even more prudent for the mobility fraternity.

With this backdrop, the Automotive Board of **SAEINDIA** conducted the first edition of a Blue Ribbon CEO Conclave in Chennai on July 25 at the Taj Coromandel during the visit of Daniel M. Hancock, 2014 **SAE International** President. Murli Iyer, International Advisor, SAE International, accompanied the President. At this first-ever conclave, 20 CEOs and heads of business from OEMs and vendor partners were present to show their continued support to SAEINDIA and share their thoughts and experiences about "Business Practices for Next-Generation Mobility."

The discussion was not limited to, but covered the following major topics: Doing Business Right—Ethics and Values, Diversity, Talent Development; Leveraging Innovation and Business Practices—PPP; Socio-economic Partnerships for Holistic Development; and Integrating Smart Mobility for Masses - Inclusive Strategy (Urban Development, Energy Providers, and Policy Makers).

The conclave began with a welcome address by Dr. Arun Jaura, SAEINDIA Automotive Board Chairman, followed by an opening address by Dr. Aravind Bharadwaj, President, SAEINDIA.

Hancock set the tone for the evening by sharing his experiences on leveraging resources across borders, deploying cross-industry technology, and business practices. He discussed practices and success stories of collaborative innovation during his 43 years at **General Motors** in different parts of the world. Hancock discussed STEM (science, technology, engineering, and math) programs and how they have made a big difference in the communities and mobility engineering fraternity in terms of nurturing science and technology at a young age. He shared anecdotes of fund-raising during the initial stages of these programs.

Suman Bose, MD and CEO, **Siemens Industry Software India**, talked about the need for a paradigm shift through disruptive thinking and radical innovation. He shared anecdotes of his team's efforts, the work being done in India and other regions on connected vehicles, and a few other examples of

Suman Bose: "Radical innovation and disruptive thinking is key to the success of next-generation mobility business practices. The sensitivity of customer needs across regions will help reverse innovation growth."

Dr. Mahadevan: "Holistic policies with industry blueprints and stronger partnerships with academia will streamline growth of next-generation mobility industry. Emphasis on unique solutions in different markets will be even more prudent and need of the hour."

how radical innovation and the way of conducting business has changed the playing field for Siemens across India and the world. He talked about technology trends, since one size does not fit all, and the various levers Siemens uses to be ahead of the curve in next-generation mobility.

Dr. Mahadevan, Board Member of **India Pistons** Ltd., shared his thoughts about a holistic approach and participation of stakeholders, how setting the policy framework was important to lay a blueprint for the industry, and consumers of mobility solutions. The sustainability of mobility solutions requires more than knee-jerk reactions of technology demonstrations. There is a need for more research partnerships with academia and government R&D labs.

Nirmal Shani, Director, South Asia, **IHS**, discussed the trends and practices IHS is tracking globally and how innovation platforms and partnerships within industry-academia has seen ideation growth in several regions of the world. Sensitivity to global needs is more important, and decisions need to be made on the ground about a product or service rather than being thousands of miles away. Open ideation and crowd sourcing are major trends in coming up with out-of-the-box solutions.

The informal interactions after the formal session revolved around alignment of stakeholders, radical innovation, socio-economic opportunities, agility in decision making, and analysis at the grassroots level. Also discussed was how becoming global was important but being technologically savvy and innovative was even more critical as we embark on next-generation sustainable mobility.

Dr. Arun Jaura, Chairman, Automotive Board, SAEINDIA

Nirmal Shani: "Sensitivity to regional markets will create a snowballing affect for the growth of global players in next-generation mobility practices. Standards and practices need to be rationalized so that stakeholders are aligned for a major mind-set change."

SUPRA SAEINDIA 2014: Applying the power of ingenuity

SUPRA **SAEINDIA** 2014 was an exciting design competition conceived to instill and harness talent, honing the skill of engineering students from all over India. Students from various colleges form teams and create a virtual design, build a prototype, and test their own Formula-type race car. The project fuels the exuberance of the youth by providing teams a platform to test their mettle, giving them pragmatic exposure to real-world challenges as faced in industry. The event happened from 18th to 20th, July 2014, at MMRT (Madras Motor Race Track) in Chennai.

The track set to flare with the key stakeholders flagging off the endurance test at SUPRA SAEINDIA 2014.

The untiring participants on the track of MMRT, Chennai.

Safety check before the endurance test at SUPRA SAEINDIA 2014.

According to Dr. S. Thirumalini, Convener, SUPRA SAEINDIA 2014, the "three-day event at MMRT saw experts analyzing the engineering design report, marketing presentation, cost analysis, acceleration, fuel economy, skid pad test, and endurance by the teams. These events were judged by a panel of eminent experts from the automotive industry. The students are given one year's time to prepare their prototype. This year 85 teams from various colleges all over India are participating in the competition."

She further added, "In this process, students learn to develop a design, understand the process of new product development, industrial procurement, manufacturing, assembly, and prototyping. The selected prototypes were then tested in standard test conditions to measure parameters like maneuverability, technological innovation, endurance, hill-climb, and stability. The objective of this event is to bring out the latent

The judging team of SUPRA SAEINDIA 2014.

SAEINDIA News

SUPRA SAEINDIA 2014 Winners		
Skid pad		
Rank	Team name	College name
1	Camber Racing	SRM University
2	Invincibles	Krishna Institute of Engineering and Technology
Autocross		
1	Team Vamos Autocross	Sinhgad Academy of Engineering
2	Team Terasvin	Sona College of Technology
Endurance		
1	Ojaswat	Chandubhai S. Patel Institute of Technology
2	Camber Racing	SRM University
Fuel economy		
1	Camber Racing	SRM University
2	Team Octane Racing	College of Engineering, Pune
Design evaluation		
1	Team Haya	PES Institute of Technology
2	Team Road Runner	National Institute of Technology, Rourkela
Cost analysis		
1	Pegasus Racing	PSG College of Technology
2	Team Wings	Maharastra Institute of Technology, Aurangabad
Marketing presentation		
1	Team Motorbreath	Veermata Jijabai Technological Institute
2	Plysteer Racing	Hindustan College of Science and Technology
Acceleration		
1	Team Terasvin	Sona College of Technology
2	Team Vamos Autocross	Sinhgad Academy of Engineering
Overall score		
1	Camber Racing	SRM University
2	Team Octane Racing	College of Engineering, Pune
3	Ojaswat	Chandubhai S. Patel Institute of Technology

Unveiling of the best presented car.

Overall first prize distribution.

talent of students so that it fulfills the Automotive Mission Plan (AMP 2016), the focus to make India an international automotive hub.

Mr. Asit K. Barma, Chairman, Media, Communications, Publications Board, SAEINDIA said: "Participants in the competition will need to drive their own cars, which they have conceived, designed, and fabricated. The specification of the car frame and engine are restricted so that the imagination, creativity, and knowledge of the students are challenged. Students realize their talent though such an experience, making them proven candidates for the future as technocrats, entrepreneurs, designers, innovators, and leaders."

The event is sponsored by **Maruti Suzuki India** Ltd. as the title sponsor and supported by **Rajalakshmi Group of Institutions**, Chennai. Other sponsors include **Continental Automotive**, **Bharat Petroleum** Corp. Ltd., **Bosch**, **Altair**, **Ansys**, **Eaton**, **Indian Oil** Corp. Ltd., **ARAI**, **Victora Tool**, and **Roots**.

Ms. Priya Gunasekar, SAEINDIA
Assistant Director, Programs Development

Industry NEWS

New testing and certification lab opens in Bangalore

The **CSA Group** on July 8 inaugurated its first testing and certification laboratory in Bangalore, India. Testing will be conducted on products from a number of industries, including automotive. "Currently, this lab is capable of tests and certification of a few automotive components related to electronics and automation...connectors, control units, etc.," Pino Chen, CSA Group

Test being run in the new CSA Group lab in Bangalore.

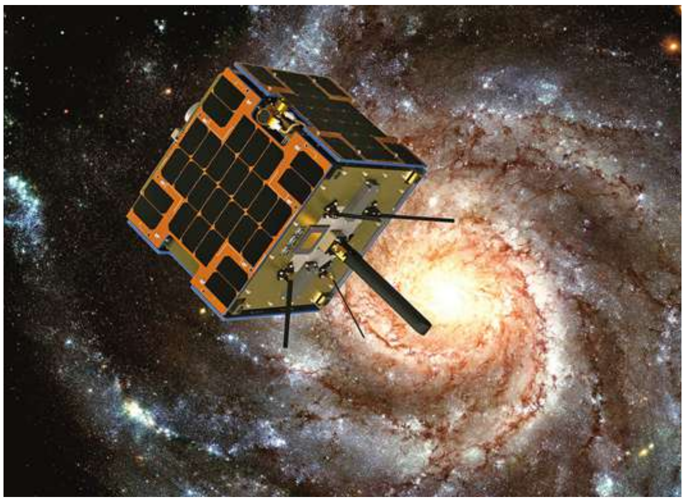
Manager of Media Relations, Asia, told SAE Magazines. "But we have a plan to expand the capabilities in coming months to cover most of the sectors in automotive." The 2500-m^2 (27,000-ft^2) lab includes cutting-edge testing equipment from North America and Europe. It is situated in the Beary's Global Research Triangle (BGRT) and is the first building to receive the platinum LEED certification from the **Indian Green Building Council** and the **United States Green Building Council**.

Agreement offers engineers in India better global mobility potential

The Washington Accord, signed in 1989, is an international agreement among bodies responsible for accrediting engineering degree programs. It recognizes the substantial equivalency of programs accredited by those bodies and recommends that graduates of programs accredited by any of the signatory bodies be recognized by the other bodies as having met the academic requirements for entry to the practice of engineering. The membership of Washington Accord is an international recognition of the quality of undergraduate engineering education offered by the member country and is an avenue to bring it into the world class category. It encourages and facilitates the mobility of engineering graduates and professionals at international level. At its meeting in June, the Washington Accord admitted the **National Board of Accreditation (NBA) of India** and the **Institution of Engineers Sri Lanka** as signatories. In the case of the NBA, recognition of programs by other signatories applies only to programs accredited by NBA that are offered by education providers accepted by NBA as Tier 1 institutions. Recognition of graduates of programs accredited by any signatory by registering or licensing bodies in other signatory jurisdictions is subject to certain restrictions. The *Economic Times* reports that "the international mobility potential of engineering graduates from Indian Institutes of Technology has not been an issue given the global recognition of these institutes, but this has not been the case with the graduates from the 1300-odd other engineering colleges in the country." The *Times* article goes on to quote the NBA's Smriti Irani: "This will ensure highest quality assurance standards to be implemented in our technical and engineering programs and provide global mobility to our engineering graduates. Graduates having degrees, which have been so accredited, would have substantial international equivalence of their achievement levels across the signatory nations. This will substantially enhance their employment opportunities around the world."

Aniara selects Dauria Aerospace to design, manufacture satellites

Dauria Aerospace, a provider of global satellite-based remote sensing information and telecommunication services, has been tapped by India-based satellite communication services provider **Aniara** to design and build two new-generation small Ku-band geostationary satellites. The geostationary satellites are specifically being developed to serve small and midsize markets in Asia, Middle East, and Africa, which are currently not being addressed or are otherwise underserved by larger and



Dauria Aerospace develops and manufactures new-generation low-cost small satellites to bring Earth imaging data and communication services directly to its customers.

more expensive satellite networks. Aniara, which is expanding its footprint in the global and regional markets, selected Dauria's small satellite platform because of its high-performance, low-cost, and streamlined construction schedule advantages. The satellites will each weigh less than 1 ton and carry up to 16 Ku-band transponders. Spacecraft are expected to be in operation by late 2017.

FSTC receives EASA approval for A320 simulator

FSTC (Flight Simulation Technique Centre) has received **EASA** approval for its **Airbus** A320 simulator, making it the only pilot training center in the region to have this approval. This is a significant achievement for FSTC, a joint venture company with **SIM Industries** BV, Netherlands, a **Lockheed Martin** Co. It has the latest Airbus 320 and **Boeing** 737-800 full flight Level D simulators located at its modern training facility in Gurgaon, India. FSTC is the first training center in North India to meet

In FSTC's full-flight simulators, one can create scenarios such as in-flight fires, electrical failures, hazardous weather, engine failures, or a combination of these.

aviation training requirements. It has been set up with a vision to reduce the burden of airlines toward travel, visa, and hotel costs and to ensure immediate availability of pilots for operation. The training center has been established to meet global standards of excellence and plans to install six full flight simulators in three stages over a period of the next 18 months.

WABCO opens second Application Engineering Center in India

WABCO recently opened a new Application Engineering Center in Pune, the supplier's second such facility in India. The new center will allow WABCO's team of application and test engineers to work closely with global commercial vehicle (CV) manufacturers in India to jointly develop customized products and solutions across a broad range of vehicle platforms, the company said in a release. WABCO plans to deploy up to 15 engineers at the center by the end of 2015. They will provide a range of system design, application engineering, and project management support to help customers develop new CV platforms and models. **WABCO India** designs, manufactures, and markets conventional braking products, advanced braking systems, and other related air-assisted products and systems.

Meritor, Brakes India expand offering of air disc brakes

Troy, MI-based **Meritor**, Inc. and brake system supplier **Brakes India**, Ltd. have signed a licensing and technology assistance agreement for the manufacture and sale of Meritor ELSA air disc brakes in India. The agreement expands on an existing licensing agreement for B-frame hydraulic disc brakes, air drum, and air disc brakes. More than five million Meritor ELSA

The companies have agreed to the manufacture and sale of Meritor ELSA air disc brakes in India.

brakes have been sold globally. In India, ELSA 225H air disc brakes have been operating on major fleets for several years, particularly on buses and coaches. Features of the ELSA range include twin tappets for optimal pressure distribution, internally synchronized tappets with travel stops for easier servicing, modular construction for improved part commonality and flexibility of installation, and optional double sealing for severe applications.

TECHNOLOGY Report

AEROSPACE ENERGY | PROPULSION

Production of satellite with first all-electric propulsion system advances

Boeing is "running on schedule" as it continues to achieve production milestones for the first of its all-electric-propulsion 702SP (small platform) satellites.

The company says the 702SP will be the world's first all-electric-propulsion satellite when it is launched later this year or early next.

Earlier this year, Boeing announced that it had completed static qualification testing, verification and assembly of the primary structures for 702SP inaugural customers **ABS** and **Eutelsat**, with the spacecraft scheduled to be launched as a pair in a stacked configuration. The initial contract was signed in 2012 between Boeing and **Satmex**. Eutelsat acquired Satmex in January 2014.

Joanna E. Climer, Communications Specialist, Boeing Space & Intelligence Systems, confirmed to **SAE** Magazines on July 10 that the program is on track.

"We will be first to launch a commercial all-electric satellite, providing customers new flexibility and next-generation technology for increased performance," Craig Cooning, Vice President and General Manager of Boeing Space & Intelligence Systems, said in a March 24 press release. "The all-electric propulsion design gives customers more affordable launch options and the ability to nearly double payload capacity."

Boeing is building two pairs of 702SP satellites under a joint four-satellite agreement with ABS and Eutelsat. Production on the 702SP satellites began in 2013, after the spacecraft passed its critical design review in May of that year.

The Boeing 702SP couples proven technology from Boeing's previous designs with next-generation technology and processes, resulting in an affordable, lightweight alternative design to meet customer needs, according to Climer. She explained to SAE Magazines that the 702SP's all-electric propulsion system relies exclusively on xenon as the propellant: "This propellant is an inert and non-hazardous element. Previous hybrid designs used a combination of xenon gas and other chemical propellants, such as hydrazine and nitrogen tetroxide. In the hybrid design, these other chemical propellants were used for both orbit-raising and positioning, while xenon gas was only used for positioning...The all-electric propulsion 702SP now uses xenon as the only propellant."

Production of the 702SP satellite is on schedule, Boeing says.

Because of the lower mass enabled by all-electric propulsion, two satellites can be launched on a single launch vehicle. Depicted here is the all-electric satellite for Boeing customer ABS. (Boeing)

Most satellites use something similar to combustion for propulsion, but since there is no oxygen in space they need to carry both the fuel and oxygen with them, "which is heavy," Climer continued. "With the xenon ion propulsion system (XIPS) engine in the 702SP, instead of using fuel and an oxidizer, you have a gas—in this case xenon. The xenon gas is charged, electrically ionized, and travels at a high velocity through the XIPS engine to create thrust, propelling the satellite forward. This makes the 702SP more efficient and lighter in weight. Weight is a main factor in launch costs."

The 702SP is an evolution of the Boeing 702 satellite. Its lightweight design accommodates launch on most commercial launch systems, including Falcon 9, Ariane 5, Sea Launch, Proton, Soyuz, Atlas V, and Delta IV.

Because of lower mass owing to the lighter-weight components of a xenon-ion propulsion system compared to that of a conventional one requiring liquid fuel, two satellites can be launched on a single launch vehicle, resulting in a cost savings of up to 20% when compared with existing launch options, according to Boeing.

The disadvantage of all-electric propulsion is that it generates less thrust than conventional propulsion and thus takes longer to move and position the satellite.

Patrick Ponticel

OFF-HIGHWAY ENERGY

Improving lignocellulosic biofuel biorefining

When making cellulosic ethanol from plants, one problem is what to do with a woody agricultural waste product called lignin. New research from scientists at **Georgia Institute of Technology**, **National Renewable Energy Laboratory**, and **Oak Ridge National Laboratory** indicates that there is a way in which lignin could be transformed from a waste product into valuable materials such as low-cost carbon fiber or bio-based plastics.

Professor Arthur Ragauskas prepares samples containing cellulose, lignin, and hemicellulose for analysis using advanced nuclear magnetic resonance techniques.

According to the researchers, using lignin in this way would create new markets for the forest products industry and make ethanol-to-fuel conversion more cost-effective.

"We've developed a road map for integrating genetic engineering with analytical chemistry tools to tailor the structure of lignin and its isolation so it can be used for materials, chemicals, and fuels," said Arthur Ragauskas, a Professor in the School of Chemistry and Biochemistry at the Georgia Institute of Technology. He is also part of the Institute for Paper Science and Technology at Georgia Tech.

The growth of the cellulosic fuel industry has created a stream of lignin that the industry needs to find valuable ways to use. At the same time, federal agencies and industry are funding research to simplify the process of taking biomass to fuels.

"One of the very promising approaches to doing that is to genetically engineer plants so they have more reactive polysaccharides suitable for commercial applications, but also to change lignin's structural features so that it'll become more attractive for materials [and fuel] applications," Ragauskas said.

Research has shown it's theoretically possible to genetically alter lignin pathways to reduce undesirable byproducts and more efficiently capture the desired polysaccharides—which are sugars that can be converted to other products—and enhance lignin's commercial value.

"There are sufficient publications and data points out there to say that, 'Yes, we can do this,'" Ragauskas said.

Through work on transgenic plants and wild plants that naturally have fewer undesirable constituents, biologists, engineers, and chemists have recently improved the biorefinery field's understanding of the chemistry and structure of lignin, which provides a better idea of the theoretical chemistry that lignin can do, said Ragauskas.

"We should be able to alter the structure of lignin and isolate it in such a manner that we can use it for green-based materials or use it in a blend for a variety of synthetic polymers," he said.

Doing so would create a stream of polysaccharides for use as ethanol fuels, with lignin waste that has structural features that would make it attractive for commercial applications such as polymers or carbon fibers.

The science could be applied to a variety of plants currently used for cellulosic biofuel production, such as switchgrass and poplar.

Today, lignin is mostly burned for energy to fulfill a small amount of the power requirements of the ethanol biorefineries.

"Our primary mission is to reduce the cost of taking biomass to biofuels," Ragauskas said. "But in the process we've learned a lot about lignin, and we might be able to do more than just reduce cost. We might be able to tailor lignin's structure for commercial applications."

Jean L. Broge

OFF-HIGHWAY POWERTRAIN

Dana brings CVP technology to lighter-duty equipment

Dana Holding Corp. took advantage of the venue of CeMAT to announce progress with its VariGlide technology, a new transmission design that incorporates continuously variable planetary (CVP) technology based on a set of rotating, tilting balls fitted between two rings.

Developed through a strategic licensing relationship with **Fallbrook Technologies** Inc., and based on its NuVinci CVT technology, the product can replace the torque converter in some transmission configurations to decouple engine speed from the vehicle's travel or working speed. Particularly suitable for the rapid acceleration, deceleration, and precise positioning required by material-handling applications, it also eliminates the need for forward and reverse clutches while reducing overall engine speeds, allowing the engine to operate at its optimum efficiency level and reduce noise levels.

VariGlide technology is particularly suited to optimize the productivity of 1.5- to 3-t (1.7- to 3.3-ton) forklifts, which account for about 80% of the global material-handling equipment market today.

With numerous power paths and no abrupt ratio changes, VariGlide technology provides an infinite number of gear ratios for improved shifting, driver comfort, durability, scalability, and efficiency when compared to conventional CVTs, according to Dana.

Numerous powersplit power path concepts for forklift applications have been analyzed, and initial simulations show projected fuel savings of up to 20% for a standard-sized forklift operating in a typical pick-and-place duty cycle. Dana is currently upfitting a 2.2-t (2.4-ton) forklift with VariGlide technology for functional evaluation.

VariGlide technology will be offered as a pre-assembled module providing a standard powersplit configuration for forklift transmissions produced by OEMs. Dana will also implement VariGlide technology in a premium configuration optimized to supply further fuel efficiency and productivity gains in select Spicer powershift transmissions.

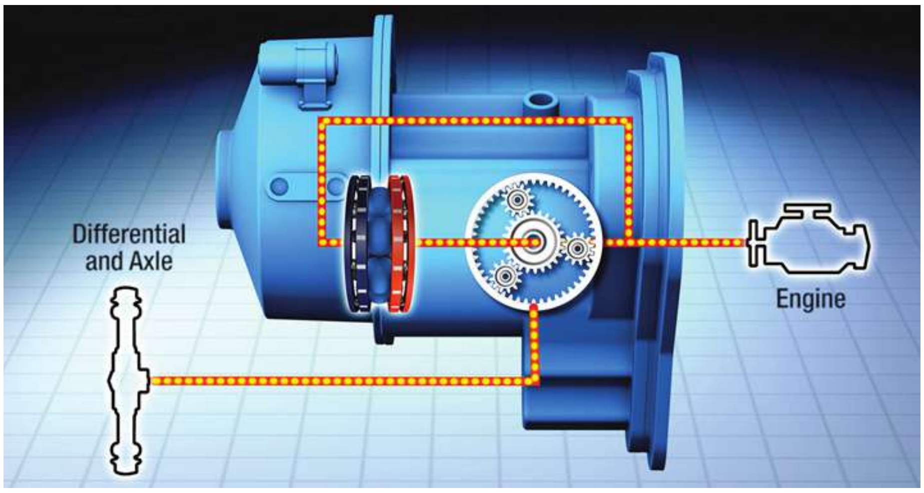
VariGlide technology is particularly suited to optimize the productivity of 1.5- to 3-t (1.7- to 3.3-ton) forklifts, which account for about 80% of the global material-handling equipment market today.

Dana says it provides "unparalleled power-path flexibility" through a unique variator design configuration. A set of spinning planets is fitted between an input disc driven by the engine and an output disc that transfers power from the variator to downstream transmission components. As power enters the input disc, the planets tilt on their axes and change ratios, depending on engine demands and controller input.

To efficiently transfer torque, a thin layer of traction fluid flows between the planets. When compressed, this traction fluid becomes momentarily rigid, allowing the torque to transfer between the planets and discs without slipping. With numerous power paths and no abrupt ratio changes, VariGlide technology provides an infinite number of gear ratios for improved shifting, driver comfort, durability, scalability, and efficiency when compared to conventional CVTs, says Dana.

The CVP technology used by VariGlide has undergone more than 70,000 h of durability testing, and leverages more than 600 U.S. and international patents and patent applications. In addition to forklift trucks, it is also a good fit for compact front-end loaders, skid steer loaders, and compact utility tractors.

Jean L. Broge



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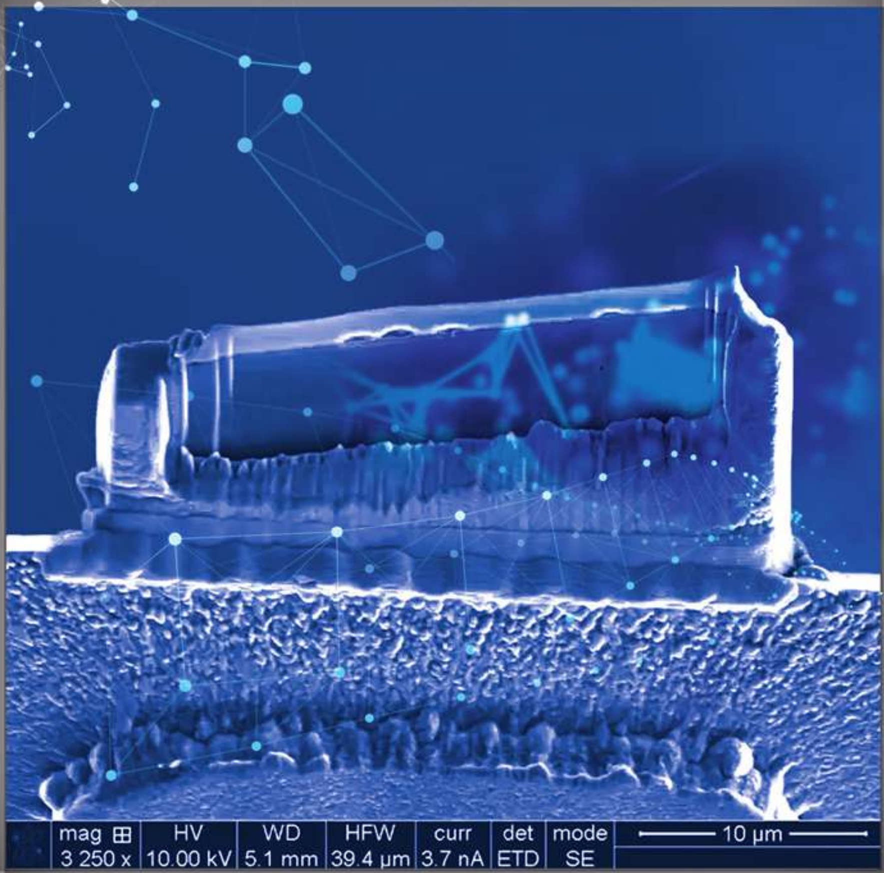
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AEROSPACE PROPULSION

Boeing 737 MAX LEAP-1B engine begins ground testing

CFM International has initiated ground testing of the first all-new LEAP-1B engine that will exclusively power the **Boeing** 737 MAX. CFM ran the engine for the first time on June 13, three days ahead of schedule. The LEAP-1B engine, installed in a test cell at **Snecma** (**Safran**) facilities in Villaroche, France, successfully completed a series of break-in runs before reaching full take-off thrust.

The engine will be on test for the next several weeks, during which time CFM will verify its mechanical operation, operability (stall margin), engine starts, and further validate the advanced technologies incorporated in the engine, including the woven carbon fiber composite fan, the Twin-Annular, Pre-Mixing Swirler (TAPS) combustor, ceramic matrix composite shrouds in the high-pressure turbine and the titanium aluminide blades in the low-pressure turbine. The LEAP-1B is specifically optimized for the 737 MAX with a smaller, highly efficient core and benefits from these new technologies.

According to Cédric Goubet, Executive Vice President for CFM, "All of the testing we have done to date has validated the technology choices we made."

The LEAP-1B engine is expected to contribute significantly to the 737 MAX's fuel-efficiency improvement. The 737 MAX will be 14% more fuel efficient than today's most efficient Next-Generation 737s–and 20% better than the original Next-Generation 737s when they first entered service.

Boeing claims that "the 737 is more fuel efficient than the A320 today and will be more fuel efficient than the A320neo tomorrow. Airlines operating the 737 MAX will see an 8% operating cost per seat advantage over the A320neo."

CFM was on track to deliver the 10,000th CFM56-7B engine for the Next-Generation 737 by the end of June, making it the best selling engine-airframe combination in history.

"The start of testing on the LEAP-1B engine for the 737 MAX demonstrates that we are on track to deliver the most fuel-efficient single-aisle airplane family in the industry in 2017," said Keith Leverkuhn, Vice President and General Manager, 737 MAX program, Boeing Commercial Airplanes.

Jean L. Broge

AUTOMOTIVE ELECTRONICS

Market for 8-bit chips remains strong

Powerful 32-bit microcontrollers often manage new features and functions, but the market for simple 8-bit controllers is holding up nicely. These devices give design teams the flexibility to get to market quickly with inexpensive modules that use little power.

STMicroelectronics has expanded its 8-bit automotive-grade microcontroller portfolio with compact, inexpensive devices that run at 20 MIPS. The CPUs also offer connectivity, timing, and analog functions for applications such as seat controllers, window lifters, HVAC controls and gateways, as well as under-the-hood systems.

Applications like these are keeping demand for simple controllers high. Tom Hackenberg, Principal MCU Analyst for **IHS Technology**, said 8-bit CPUs accounted for 24% of the automotive microcontroller market last year. He predicts that 8-bit chips will decline only slightly in 2018, dropping to 22%.

"Companies like **Microchip**, **Renesas**, **NXP**, **Atmel**, **Freescale**, **Cypress**, **Infineon**, **Silicon Labs**, STMicro, and many others have continued to advance the power efficiency and integration features of 8-bit solutions to keep this market thriving for the foreseeable future," Hackenberg said.

Chip marketers and analysts explain that there are many applications where the sub-$1 price of 8-bit chips is only one of their attractive features. With more and more electronics in vehicles, engineers see many reasons to deploy the small devices.

"They offer low pricing, small packages, and low power consumption," said Christophe Loiodice, Product Line Manager at STMicroelectronics. "More and more mechanical systems are being replaced by electronic applications. Time-to-market is very important, so many engineers pick 8-bit chips because they're easy to use. The tasks don't need a lot of software, so large memory sizes aren't important."

New regulations are also helping fuel demand for simple chips. In the U.S., rearview cameras are being mandated, opening up a new high-volume market.

"Developers want small packages;

STMicro's 8-bit CPUs meet demands for low-simple, power electronic controls.

often a rearview camera's printed circuit board is only 2 mm square," Loiodice said. "These applications also need low power; automakers want solutions that help them reduce power consumption."

Hackenberg predicts that 32-bit CPUs will soon account for more than half the automotive CPU sales, but he sees many new roles for 8-bit chips.

"As more nodes share their operational status, sensor data, or other information, most of the controllers will only need basic modes—basically waking, transmitting, and going back to standby," he said. "They'll also see use with small motors that do nothing but infrequently readjust a seat or window position. The 8-bit market will benefit strongly from new power/price-sensitive Internet of things connectivity."

Even as these simple systems evolve, they aren't expected to migrate up to 16-bit CPUs. As 32-bit CPU pricing declines and 8-bit capabilities rise, they're squeezing out 16-bit chips. Hackenberg predicts that 16-bit usage will shrink from 31% last year to 23% in 2018.

Loiodice noted that STMicro hasn't introduced a 16-bit chip since 2009. He said that the drive to make cabins more comfortable and increase options for drivers and passengers is also helping maintain demand for these chips.

"If you use dedicated 8-bit controllers, it's much cheaper to replace a module for one function than to replace one multi-function controller," Loiodice said. "Another factor is that not all modules in the dashboard are made by one company. The Tier 1s use small, inexpensive controllers for each module."

Terry Costlow

ELECTRONICS

The drive for driverless vehicles

Autonomous vehicles are a hot topic, most noticeably in the automotive world where high-profile projects such as the **Google** Self-Driving Car receive plenty of press. But automated driving/operation is making significant headway in the off-highway realm as well, especially in mining applications. Safety is a primary reason companies are pursuing autonomous vehicles/equipment, but safety is also a major obstacle to widespread implementation. Legislation, for example, has been signed in certain states to allow the testing of automated vehicles on public roads, but at least in Michigan the law requires a human in the driver's seat at all times—just in case.

As part of **AUVSI**'s Unmanned Systems 2014 Conference that took place in May, **SAE** helped to organize a panel of experts around the topic "On-Road and Off-Road Technologies for Automated Vehicles and Equipment." During this session, industry experts from the OEM and supplier communities discussed the benefits, barriers, and challenges involved with greater autonomy. John Williamson, Manager–Autonomous Vehicle Development, United States Technical Center 2, **Komatsu America** Corp., and Serge Lambermont, Technical Director Automated Driving at **Delphi Electronics & Safety**, were two of those experts who provided their insights, some of which are included here.

Consistency of operation and increased utilization are significant motivators for increased automation in mining, according to John Williamson of Komatsu America Corp.

Object detection, localization, and accurate and updated map data are areas in which technology still needs improvement for more widespread adoption of automation, said Serge Lambermont of Delphi Electronics & Safety.

Where is the genesis of choosing which systems are prime for automation, and what factors go into this analysis?

Serge: In the automotive industry most of the analyses are deductive and existing systems and infrastructures are optimized for automation; in most cases, it is driven by safety, cost improvement, and convenience.

John: In the mining realm, the market has driven research in automation of haul trucks. There are several remote locations where personnel have to be flown in and out to work, and other competing industries in these regions also compete for workers. In this case, the factors that come into effect for analyzing automation are cost, safety, and consistent operation.

What system or area of a vehicle have you found thus far to hold the most opportunity for automation?

Serge: Safety—many accidents can be avoided by active safety systems.

John: In mining, we have automated the full operation of the haul truck. Currently the only time there needs to be human interaction is for errors, maintenance, and fueling.

What would be considered the primary motivator to automate a vehicle?

Serge: The immediate motivator is safety and the increase of connectivity in the vehicle, which could distract the driver.

John: Mainly cost, but consistency of operation [and] increased utilization are also important.

Where are there technology lags that are stunting development and integration of automation?

John: Technology is keeping up fairly well, but I would say most of the room for improvement is in GPS-less navigation and obstacle avoidance technology.

Serge: Perception and object detection, localization, [and] accurate and updated map data.

Are current communication standards like SAE J1939 robust enough to support a job site full of autonomous machines?

Serge: Automated vehicles sometimes require central processing of sensor data as, for example, is supported by the Delphi multi-domain controller. This communication requires a higher bandwidth than CAN. Flexray and Ethernet are alternatives with higher bandwidth and a higher level of functional safety. Delphi supports CAN, Flexray, and Ethernet with automotive-grade hardware components (controllers, interface, wiring, wiring design, and functional safety decomposition).

Are there particular off-highway industries that are more accepting of automated systems?

John: I feel that the mining industry has embraced automation very well. The mining area can be segregated and controlled easier than other systems such as highway and other applications.

How are equipment operators reacting to the use of autonomous machines in mining? Has there been any pushback for fear of job losses?

John: In mining, so far the implementation has been in regions where there is a shortage of workers, so not much pushback so far. Also, more desirable jobs are being created in these areas in terms of pit supervisors, central controllers, and autonomous mining technician jobs.

Ryan Gehm

ENERGY

A look inside lithium-ion batteries

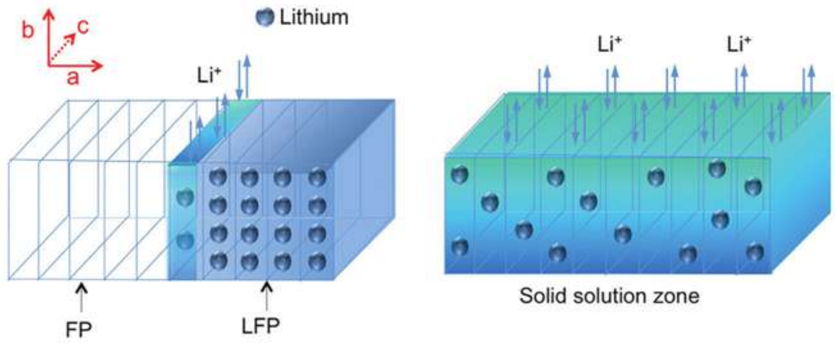


Diagram illustrates the process of charging or discharging the lithium iron phosphate (LFP) electrode. As lithium ions are removed during the charging process, it forms a lithium-depleted iron phosphate (FP) zone, but in between there is a solid solution zone (SSZ, shown in dark blue-green) containing some randomly distributed lithium atoms, unlike the orderly array of lithium atoms in the original crystalline material (light blue). This work provides the first direct observations of this SSZ phenomenon. (MIT)

A group of researchers from **MIT** says it has observed the inner workings of a type of electrode widely used in lithium-ion batteries, and may be able to explain "the unexpectedly high power and long cycle life of such batteries." The group consists of MIT postdoc Jun Jie Niu, research scientist Akihiro Kushima, Professors Yet-Ming Chiang and Ju Li, and three others.

The electrode material studied, lithium iron phosphate (LiFePO4), is considered an especially promising material for lithium-based rechargeable batteries; it has already been demonstrated in applications ranging from power tools to electric vehicles to large-scale grid storage. The MIT researchers found that inside this electrode, during charging, a solid-solution zone (SSZ) forms at the boundary between lithium-rich and lithium-depleted areas—the region where charging activity is concentrated, as lithium ions are pulled out of the electrode.

Li says that this SSZ "has been theoretically predicted to exist, but we see it directly for the first time," in transmission electron microscope (TEM) videos taken during charging.

The observations help to resolve a longstanding puzzle about LiFePO4: In bulk crystal form, both lithium iron phosphate and iron phosphate (FePO4, which is left behind as lithium ions migrate out of the material during charging) have very poor ionic and electrical conductivities. Yet when treated—with doping and carbon coating—and used as nanoparticles in a battery, the material exhibits an impressively high charging rate. "It was quite surprising when this [rapid charging and discharging rate] was first demonstrated," said Li.

"We directly observed a metastable random solid solution that may resolve this fundamental problem that has intrigued [materials scientists] for many years," said Li, the **Battelle** Energy Alliance Professor of Nuclear Science and Engineering and a professor of materials science and engineering.

The SSZ is a "metastable" state, persisting for at least several minutes at room temperature. Replacing a sharp interface between LiFePO4 and FePO4 that has been shown to contain many additional line defects called "dislocations," the SSZ serves as a buffer, reducing the number of dislocations that would otherwise move with the electrochemical reaction front. "We don't see any dislocations," Li says. This could be important because the generation and storage of dislocations can cause fatigue and limit the cycle life of an electrode.

Unlike conventional TEM imaging, the technique used in this work, developed in 2010 by Kushima and Li, makes it possible to observe battery components as they charge and discharge, which can reveal dynamic processes. "In the last four years, there has been a big explosion of using such in situ TEM techniques to study battery operations," said Li.

A better understanding of these dynamic processes could improve the

performance of an electrode material by allowing better tuning of its properties.

Despite an incomplete understanding to date, lithium iron phosphate nanoparticles are already used at an industrial scale for lithium-ion batteries. "The science is lagging behind the application," Li said. "It's already scaled up and quite successful on the market. It's one of the success stories of nanotechnology."

"Compared to traditional lithium-ion, [lithium iron phosphate] is environmentally friendly and very stable," said Niu. "But it's important for this material to be well understood."

While the discovery of the SSZ was made in LiFePO4, "The same principle may apply to other electrode materials. People are looking for high-power electrode materials, and such metastable states could exist in other electrode materials that are inert in bulk form...The phenomenon discovered could be very general, and not specific to this material," said Li.

The research was supported by the **National Science Foundation**.

Jean L. Broge

AUTOMOTIVE INTERIORS

Dirac claims 'new approach' to sound optimization

Unison is an extension of the concept of room correction, in which each speaker is equalized not only by means of a single filter at the speaker's input, but by using all other speakers in the system to help the main speaker attain an ideal target impulse and frequency response.

Volvo is making **Dirac**'s "active acoustic treatment of the listening space" technology (called Unison) available in the new XC90 with the **Bowers & Wilkins** audio system. According to Dirac, Unison co-optimizes the loudspeakers in frequency, time, and space for the "best possible bass integration and clarity," enabling re-creation of individual acoustic environments from certain performance venues such as Gothenburg Concert Hall located near Volvo headquarters.

In an e-mail response to **SAE** Magazines, Dirac's Lars-Johan Brännmark explained the technology:

"Unison is an extension of the concept of room correction, in which each speaker is equalized not only by means of a single filter at the speaker's input, but by using all other speakers in the system to help the main speaker attain an ideal target impulse and frequency response. The loudspeaker to be equalized is called main speaker, and the rest of the speakers are called support speakers. The role of the support speakers is generally twofold: to extend the frequency range of the main speaker, in cases where the main speaker is band-limited; to actively counteract the acoustic response of the room caused by the main speaker.

"In a traditional single-channel approach to room correction, each speaker is viewed as a main speaker, and support speakers do not exist. A single-channel correction filter can adapt the time and frequency response of the main speaker so that it interacts as smoothly as possible with the acoustics of a given room. However, neither the speaker's frequency range nor the room acoustics can be significantly changed.

"Using Dirac Unison, the room acoustics can be altered in ways that are impossible to achieve with single-channel equalization. Speakers located at various positions in the room can act in-phase with the main speaker and out-of-phase with the room response, thus enhancing the main speaker and suppressing the influence of the room."

According to Volvo, the system uses a combination of high-performance, low-distortion speaker designs, including extended-range aluminum tweeters and Kevlar midrange units, reflecting components found in Bowers & Wilkins premium loudspeakers. It also features a center speaker with Bowers & Wilkins tweeter-on-top technology for the first time in a car, providing a more open, spacious sound.

Specifically, the system consists of a 12-channel **Harman** 1400-W Class D amplifier serving a total of 19 Bowers & Wilkins speakers—seven Nautilus tweeters (25 mm) with the latest treble technology; seven midrange speakers (5 x 100 mm and 2 x 80 mm) with the characteristic yellow Bowers & Wilkins Kevlar cone clearly visible behind the cover; four cone woofers (200/165 mm); and the new, groundbreaking air-ventilated subwoofer (250 mm).

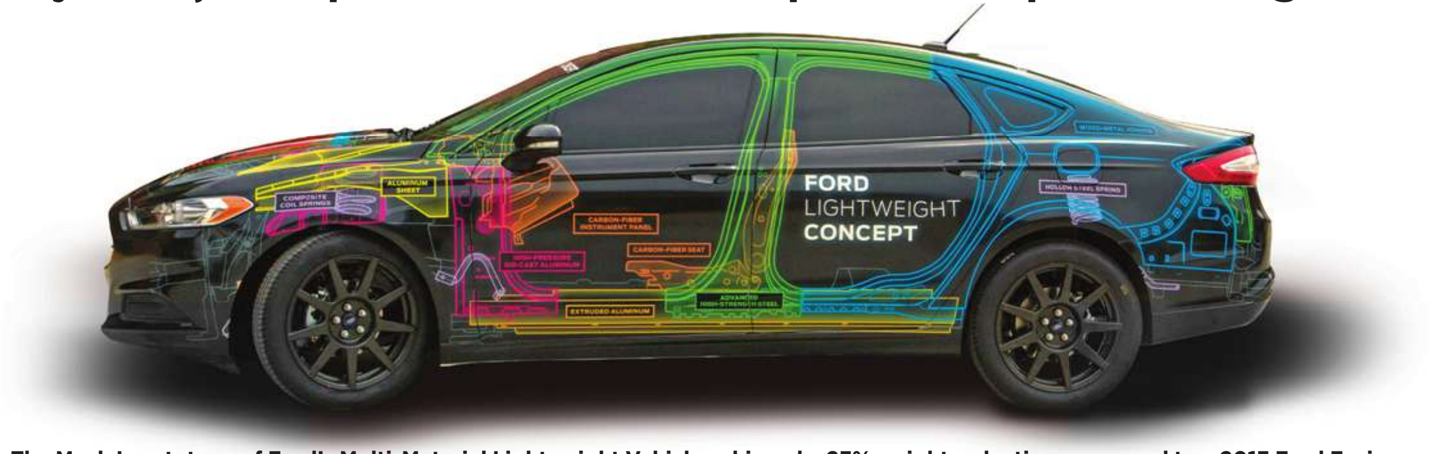
Dirac's sound-processing software manages the timing of the sound and cooperation between the speakers to optimize the sound for a specific seating position, or all seating positions.

"Each loudspeaker in the system, subwoofers included, will produce the exact and proper amount of each source signal, in such a way that the desired time and frequency responses are reached at the listener's position," said Brännmark. "The desired responses are determined based on the locations of the main loudspeakers. Thus, a main speaker may itself be band-limited and lack the ability to reproduce low frequencies. However, if optimized with Dirac Unison, the main speaker will exhibit a well-timed full-frequency-band behavior thanks to the support provided by other speakers in the system."

Patrick Ponticel

AUTOMOTIVE BODY | CHASSIS

Hyundai, Ford pursue structural composites despite challenges



The Mach I prototype of Ford's Multi-Material Lightweight Vehicle achieved a 23% weight reduction compared to a 2013 Ford Fusion.

The lightweighting potential of composite materials is undeniable. But harnessing that potential in a reasonably economic way is the crux to widespread composites use in vehicle structures.

Within the **Hyundai Motor Group** conglomerate is a steel company, **Hyundai Steel**, so material challengers have to impress on several fronts—not just proving lighter weight—to overtake steel for a given vehicle application. Chi-Hoon Choi of Hyundai Motor Co., who holds a Ph.D. in Polymer Science and Engineering, said as much during the "Structural Plastic Composite Components: Pathway to Adoption" technical session at **SAE** 2014 World Congress.

"High-strength steel (HSS) is one of the most useful materials when we want to reduce the weight of a body-in-white (BIW)," Choi said. Hyundai now employs HSS of 1.0 to 1.5 GPa using a hot stamping process. "So we have to develop a specific composite to replace that kind of part...If we want to apply composite materials instead of light metal or high-strength steel, we have to develop a unique design concept."

One example was a battery pack case that Hyundai researchers tried to develop for the i10 EV (electric vehicle). The goal was to develop a one-piece composite case as opposed to the steel case that consisted of more than 20 parts.

"The cost of the [initial CFRP] composite case was much higher than the steel one, so we decided to develop a PP (polypropylene) based product reinforced with glass fiber instead of CFRP (carbon-fiber-reinforced polymer)." The result was a three-piece battery pack case that was 10 kg (22 lb) lighter—about 24 kg (53 lb) vs. 34 kg (75 lb) for the steel case.

Another current Hyundai project is the development of an exterior body panel—a hood, in particular—made of composite material. Phase I involves materials development and processing including injection molding and the RTM (resin transfer molding) process. Phase II—concept design and prototyping—will begin second half of 2014, according to Choi.

(Hyundai also revealed the Intrado concept at the 2014 Geneva Motor Show, boasting a CFRP structure. See the April 1, 2014, issue of *Automotive Engineering* to read more.)

The first phase of a technology road map Choi presented revolves around the execution of long, glass, semi-structural composites in the 2015 time frame. The second phase, in the 2020 time frame, consists of continuous, carbon, structural composites.

"Composites applications for structural parts will be the biggest challenge of lightweight technology," he said. "We have to develop low-cost carbon fiber—around $10/kg—if it is possible."

That price point—if not even less expensive—must be achieved before **Ford** seriously considers placing a significant amount of CFRP composites in its mainstream vehicles, as well.

"Certainly $30 or $40 a kilo—where carbon fiber is now—we're not ready to put it on our **Ford** Focus, at 1.4 million vehicles a year, yet," said David Wagner, Technical Leader in Vehicle Design, Research, and Advanced Engineering at Ford Motor Co.

For the Multi-Material Lightweight Vehicle (MMLV) project, a collaboration between the **U.S. Department of Energy**, **Vehma International Engineering** (the U.S. R&D arm of **Magna International**), and Ford, the goals were to create a drivable prototype at a 25% weight reduction (Mach I) and to design a vehicle with a 50% weight reduction (Mach II). Unlike the Mach II design, which is carbon-fiber-intensive particularly in the body and chassis structures, the Mach I prototype makes more sparing use of the costly material.

"As far as the value to Ford Motor Co., it's going to be awhile before we have a lot of carbon fiber in a Focus," Wagner said. "So we're prototyping the parts that are going to be most valuable to us in the near term."

Those parts include a carbon-fiber instrument panel and cross-car beam that integrates the HVAC ducts, carbon-fiber seats, and carbon-fiber wheels from **Carbon Revolution** that are 45% lighter. In the powertrain area, Ford collaborated with **BASF** and others to use carbon fiber for the front cover, oil pan, and cam carrier (aluminum is still used for the head).

Though not of carbon fiber, glass-epoxy composite front coil springs from **Sogefi** are also featured on the MMLV and offer more than a 50% weight savings. The supplier uses a "lost core" process to make the springs.

"This [process] is kind of equivalent to

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Composite (left) and hollow steel coil springs are featured on the Ford lightweight concept vehicle.

what our engine-block folks do all the time, so it's not out of the question, it's just different; it's not how the steel guys make springs," Wagner said.

The prototype vehicle uses advanced high-strength steels and aluminum sheet, castings, and extrusions extensively for the BIW and closures, with a small magnesium casting employed in the front doors.

"We're looking at [carbon fiber to be] at $5/lb; I wouldn't buy it at $8 yet, and that's the fiber only," he said.

For the Mach II CAE design, most of the passenger cell consists of carbon-fiber composites. "The layups are spectacular," Wagner said. "We don't think this is quite manufacturable yet. The front rails are still likely to be in aluminum, and portions of the B-pillar will still be in boron steel because roof strength is really tough to achieve."

At the midpoint in the design process, the Mach II BIW currently achieves a 45% weight reduction against the benchmark. The team would like to raise that figure to above 50%.

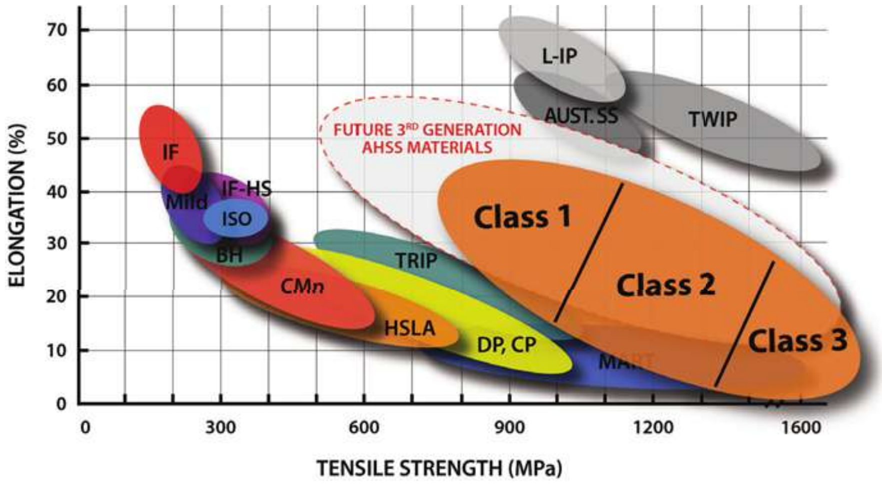
"For the longer term, you need to get [carbon fiber] into the body and chassis—saving tens of kilos rather than single digits of kilos. That's going to be a long time," said Wagner. "Aluminum vehicles are coming more strongly into the industry, and it's going to be another decade before we see much headway for lots of carbon fiber in body and chassis."

Cost is the "overwhelming aspect" to this implementation delay, he added: "It's cost of material, it's cost of making the parts, it's cost of assembling the parts, it's cost of what changes you make to your vehicle assembly, and what changes you make in your coating systems."

Ryan Gehm

AUTOMOTIVE BODY | CHASSIS

High-strength sheet steel that bends



Graph compares strength vs. elongation properties of current and NanoSteel (orange) AHSS sheet grades.

Basic vehicle structures have traditionally been stamped from sheet steel, but stricter fuel-economy standards have the auto industry turning increasingly to more costly alternative materials including thin-gauge advanced high-strength steel (AHSS) grades that unfortunately do not stamp well, or light-but-strong aluminum alloys and fiber-reinforced polymer composites, which entail costs not just from the materials themselves but from the need to retool assembly lines and reconfigure supply chains to use them.

Metallurgists in industry and academia are working overtime to develop so-called third-generation AHSS grades whose enhanced physical properties—high strength plus ready formability—aim to keep steel ahead in the frame game. But those developmental high-performance steel alloys have yet to hit the market.

Now a dark-horse newcomer is trying to elbow its way into this budding market. NanoSteel, a family of nanostructured ferrous alloys, offers high elongation properties at ambient temperatures, which provides cold-forming capabilities not seen in current high-strength steels, which are brittle.

NanoSteel of Providence, RI, which developed the new AHSS alloys, is working to provide samples for trial by companies such as **General Motors** as the new metals undergo production trials, said the inventor, Daniel Branagan, Chief Technology Officer and founder. The company hopes to license the technology to industrial users.

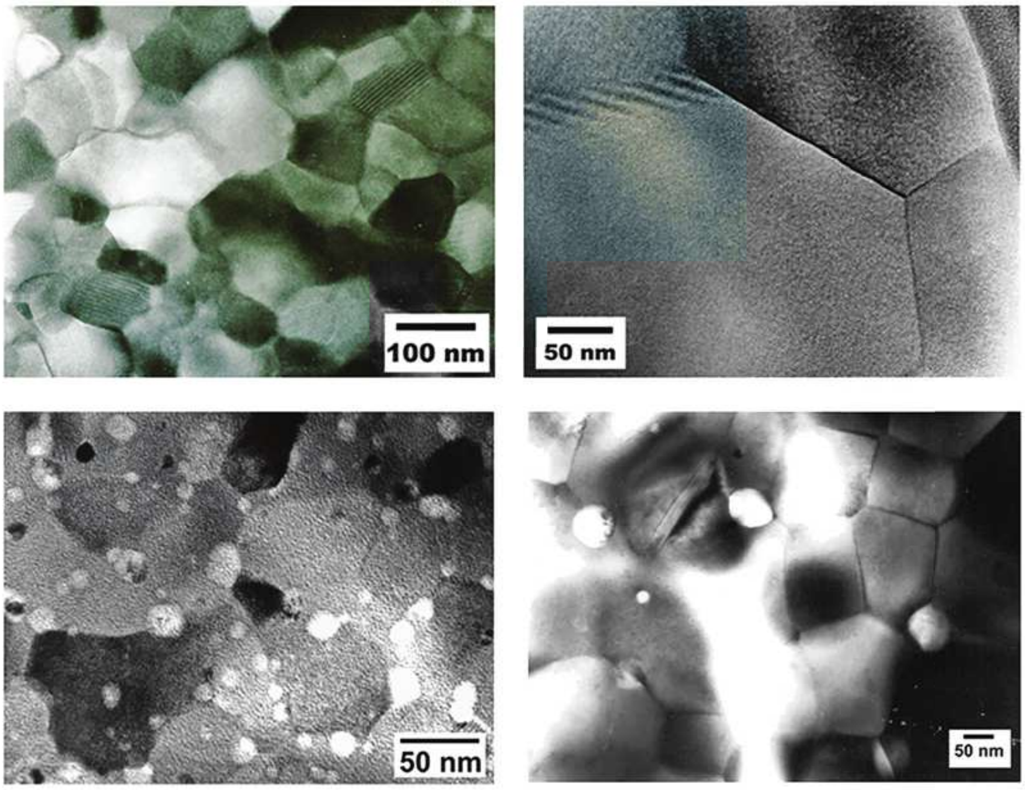
New class of steel sheet

"Today, when car designers are fighting to save every gram, steel mills have found that current AHSS alloys are difficult to form, which has opened opportunities for aluminum and composites," Branagan said. "We're trying to keep steel in cars with what we think is a game-changing technology with much better formability. We made NanoSteel sheet so that designers could use less steel to get lighter but still maintain safety."

"This is a whole new class of sheet steel alloys with unique combinations of properties that we make using a pathway that differs from those of conventional steels," he claimed.

The metals, he explained, exploit new mechanisms to provide high strength plus cold formability, which include using novel alloy chemistries, unique nanoscale grain and phase structures less than 100 nm in width, and specific structural formation pathways that have not been used before. In addition, "everything we develop is designed to be used on existing production equipment," which is crucial to early adoption by industry.

The route that Branagan took to develop NanoSteel stretches almost two decades. It began, he recalled, in the 1990s at the **U.S. Department of Energy**'s **Ames Laboratory** in Iowa,



Side-by-side comparisons of grain-size growth when iron-based nanomaterials are heated.

where he was working on nanomagnetic materials such as neodymium-iron-boron magnets. The scientist designed nanomaterials for enhanced magnetic resistivity and energy density, often using devitrified metallic glasses (amorphous) and refining the grain sizes to small diameters to achieve better single magnetic domain behavior.

Eureka moment

"Then in 1996 at Idaho National Lab, I had my 'Eureka!' moment when I realized that I could apply the same techniques to steel," Branagan said. "But rather designing for enhanced magnetic properties, I saw that if you could refine the grain size you could get much more strength. Right away I looked up the theoretical strength of iron's atomic bonds and found that most steel is around 10% to 12% of that value, so it was clear that a lot could be done to harness more of the total potential strength of iron compounds."

By 2002, Branagan and his colleagues had formed a company to commercialize his patented research, always with the ultimate aim of producing nanostructured steel sheet somewhere down the road.

"We've been following the same road map ever since—a kind of golden path—that we hoped could bring what was considered an old technology into the 21st century. Of course, nowadays high-strength steel is in the technical news every day," he said.

NanoSteel's initial product offering was a micron-thick protective coating for oil mining that provided "basically the hardness of a ceramic like alumina and the wear-resistance of tungsten carbide," he said.

In the next few years, the company introduced a thermal spray technology that produces a shield coating about a thousandth of an inch (25 microns) thick, and then a weld-overlay product that creates layers from 10 to 12 mm (0.39 to 0.47 in) thick.

Many rivers to cross

"But back in 2006 there were many tough challenges to solve," Branagan continued. "Once we turned our focus toward cold-formable high-strength sheet steel, we were confronted with the fact that though we could get to strengths that were around 50% of theoretical maximum, we had essentially hit a wall. We could create nanostructures with sufficient strength, but developing the high ductility we needed turned out to be an even bigger challenge.

"We soon realized that all existing strategies were dead ends for this because all the kinetics are wrong," he said. "Steel alloy grains grow at 80% or 90% of its melting temperature." How could a nanostructured metal "get through a large-scale industrial steel process where you have very high temperatures up to and above steel's melting point and slow cooling rates? For example, you can heat-treat a coil of sheet and it can take 6 h for its condition to homogenize."

For the next few years NanoSteel's R&D team searched for a mechanism that could provide ductility at high temperature. "Eventually, we found the kinetic and reaction pathways—the thermochemistry—to bring the nanostructure to where we wanted."

As in all of its products, the company's sheet steel solution begins with alloy compositions that differ greatly from the norm, with 10 to 20 atomic percent of P-group elements—the "boron-carbon-nitrogen-oxygen-fluorine" rank of the periodic table, which are much higher than standard levels.

"These 'nontraditional' alloying elements are actually widely used conventionally, but only sparingly because they make steel strong but brittle," he said. "In our case, we had started out using very high atomic

Daniel Branagan, the CTO and founder of NanoSteel, as well as inventor of the company's technology.

percentages of P-group elements. That's how we achieved our high strengths."

High-temperature shrinkage

Then the researchers found ways to enhance ductility via unique microconstituent nanostructures that, contrary to expectations, undergo static nanophase refinement at high temperatures rather than coarsening, producing grains and phases that are an order of magnitude smaller, together with the ability to strain-harden during cold deformation with the creation of nanoscale precipitates through a "dynamic nanophase-strengthening mechanism."

The first process yields tiny matrix grains of dendritic (finger-like) austenite crystals with complex boride pinning phases that keep everything in place, while the second transforms the austenite matrix grains to ferrite with high fractions of nanoscale phase precipitates.

"This is a different kind of nanotechnology," Branagan concluded. "People are more familiar with particulate efforts that focus on building nanomaterials one atom at a time or from small groups of atoms. We're kind of doing the same thing but in bulk by using thermochemical-enabling mechanisms that allow the structures to change at high temperatures and still have all the atoms simultaneously form the nanostructures we need."

Steven Ashley

AEROSPACE MANUFACTURING | MATERIALS

3-D manufacturing of titanium components takes off

This warm air mixer is a component designed by Northrop Grumman for the U.S. Navy's unmanned combat aerial surveillance system. CalRAM fabricated this complex component in one piece from Ti-6Al-4V using its EBM technology. If traditional manufacturing processes were used, then this component would have been made in several pieces that would have to have been joined. The demonstration of part count reduction without the need for tooling illustrates how additive manufacturing can be used to reduce cost and shorten delivery schedule.

With such challenges as base closings, shrinking defense budgets, and sequestration, the worldwide maintenance, repair, and overhaul (MRO) sector is projected to experience a significant decline over the next few years.

According to Hal Chrisman, leading analyst and Vice President at aviation consultancy **ICF SH&E**, "it appears that defense operations and maintenance spending will drop nearly 8%." He added "forecasting, which is especially critical in the aftermarket world, is very tricky this year."

Underscoring this problem, international aerospace and defense consultant **IHS** stated in its report Overcoming MRO Supply Chain Dysfunction, "Look closely at the product life cycle within the typical MRO organization and you'll notice that 50% of open work orders are waiting for parts; 30% of in-house stock will never be used; 8% of SKUs are duplications; and, on average, employees spend 25% of the workday looking for parts."

Parts management becomes even more critical as the military fleet ages and consumes all available replacement parts. MRO operators must face difficult financial choices in controlling these costs: either replicate components such as those made from titanium from scratch through a lengthy and costly remanufacturing effort, or delay those expenses by cannibalizing other aircraft for "used" replacement parts, thereby decreasing the reliability of repaired aircraft while rendering some aircraft un-flyable.

Tool-less additive manufacturing

To address such issues, a cost-effective manufacturing technology is being applied to titanium parts manufacturing for the MRO, aviation, and defense industries. **CalRAM** fabricates 3-D, near-net-shape components by melting titanium (and other metal) powders one-layer at a time using an electron beam. Employing electron beam melting (EBM) machines built by **Arcam**, CalRAM's tool-less additive manufacturing technology is said to "rapidly create solid titanium objects faster and with less cost than traditional methods."

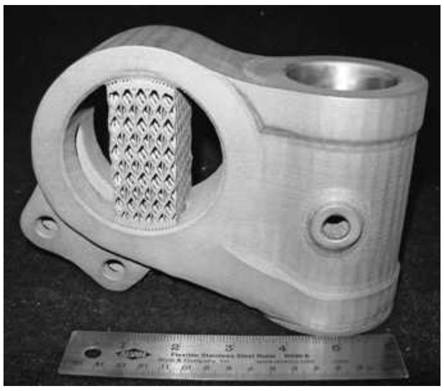
Located in Simi Valley, CA, just north of Los Angeles, CalRAM says it is the only independent AS9100C certified, EBM-based manufacturer in the U.S. Offering this technology to MROs and other suppliers in the aviation and aerospace industries, the company has been producing titanium components for airframe primes and gas turbine engine aircraft manufacturers for almost a decade.

During CalRAM's manufacturing process, electron beam paths are defined by proprietary software that "slices" existing 3-D design models into a series of separate layers, much like the views in a modern CAT scan. Powder is spread on the "start plate" by a traversing rake in the build chamber and then sintered to the plate using heat from the electron beam.

After the layer is sintered to ensure a conductive path for the electrons, the beam passes over the surface a second time at higher energy to melt and consolidate material that will form the finished part. This process is repeated, layer-by-layer, until the entire part is complete. Since parts are formed directly in the powder bed, EBM is fast with maximum build times less than 60 h. And because EBM requires absolutely no custom tooling, the company's layer-build components can save 85 to 90% of the MRO operator's cost for replacing titanium products.

The process is said to also save designers up to 90% of their development time by substantially compressing the "design-test-redesign" process as well. After receiving the customer's CAD file, CalRAM can deliver a titanium component in about two weeks, making development hardware available for installation and testing in days instead of months. Further iterations, if required, follow the same path, significantly reducing a client's time to market.

Speed and lower manufacturing costs are not the only benefits of CalRAM's EBM manufacturing process. With additive manufacturing, "complexity is free." To save weight and improve performance, engineers have almost complete geometric freedom to include otherwise impossible to fabricate elements such as holes, stiffeners, overhangs, and meshes in their designs.



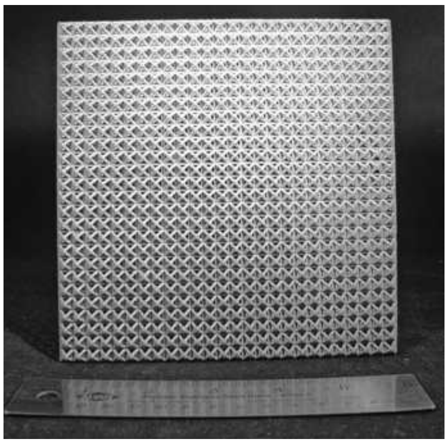
This landing gear knuckle illustrates how electron beam melting (EBM) technology can be used to produce one-of-a-kind parts rapidly without any tooling. Since the part is built layer-by-layer, the microstructure is completely uniform regardless of whether a thick section or thin section is examined. This homogeneous microstructure translates into uniform, consistent mechanical behavior. The material possesses complete isotropy. Thermal shunts fabricated as the part is being built (visible on the part) are used to keep the temperature isothermal and are easily broken off after the part has been built.

Iso grid and lattice block structures are actually cheaper to manufacture than less complex designs because they use less material and therefore take less time to produce. In one example, the company built a warm air mixer for **Northrop Grumman**'s unmanned combat aerial system that is being developed for the **U.S. Navy**. The layer-build component resulted in part count reduction and elimination of post-production assembly costs and time while still being able to meet all of the engineering design requirements.

EBM advantages over laser melting

The EBM fabrication process CalRAM has implemented is generally a higher quality alternative to laser melting manufacturing for titanium components. Operating in a vacuum instead of an inert gas environment, EBM minimizes oxygen contamination of the titanium melt, leading to improved microstructure with excellent mechanical and physical properties.

The high temperatures used during EBM (700°C for titanium and up to 1000°C for other materials including nickel-based superalloys) leave parts stress-free after cooling, eliminating the need for separate post-build thermal treatments to develop full titanium mechanical properties.



This mesh structure shows the level of detail that can be generated by CalRAM's EBM manufacturing technology. This useful feature for removing weight allows for very high specific properties (strength/density; stiffness/density) to be generated. The mesh structure can also be used to produce a surface with controlled porosity, allowing for enhanced bonding to composites.

Also, because of the higher energy of the electron beam compared to a laser (3 kW vs. 700 W), EBM is much faster than laser-based processing, producing material at rates up to five times that of laser methods.

Although titanium is often the best material for certain aircraft applications, the metal's high costs, design challenges, and lengthy time-to-design have often prevented its use. Consequently, whenever possible, engineers have selected machined or investment cast aluminum as an alternative material (with appropriate design modifications to adjust for the metal's lower strength), or heavier steels when aluminum was not a satisfactory replacement.

With additive technology EBM technology, engineers can reconsider using titanium over more the aircraft, given the cost and schedule benefits of the process.

More on the EBM process

The process starts with a customer's CAD file. Following a series of proprietary design rules to ensure parts can be built successfully in the Arcam machine, CalRAM technicians lay out the required part in a virtual build space. Temporary features may be added to provide physical support to the part as it takes shape during the build.

The product's formation begins after the chamber is heated to build temperature, when the first layer of powder (typically 50–70 μ thick) is spread over the start plate by an internal rake. All of the material in the first layer is sintered to the start plate and when melted in place becomes part of the finished assembly.

After the melt layer is complete the start plate is lowered the thickness of a single layer, the rake distributes fresh powder and the cycle continues. When the part is complete the material is allowed to cool in the machine chamber.

The "brick" containing the parts is removed from the machine and sent to the powder recovery station where sintered powder is separated from the finished parts. When the parts are cleaned, they are typically sent to a hot, isostatic press (HIP) facility, where the high pressures and elevated temperatures heal any internal micropores, thus increasing product fatigue life.

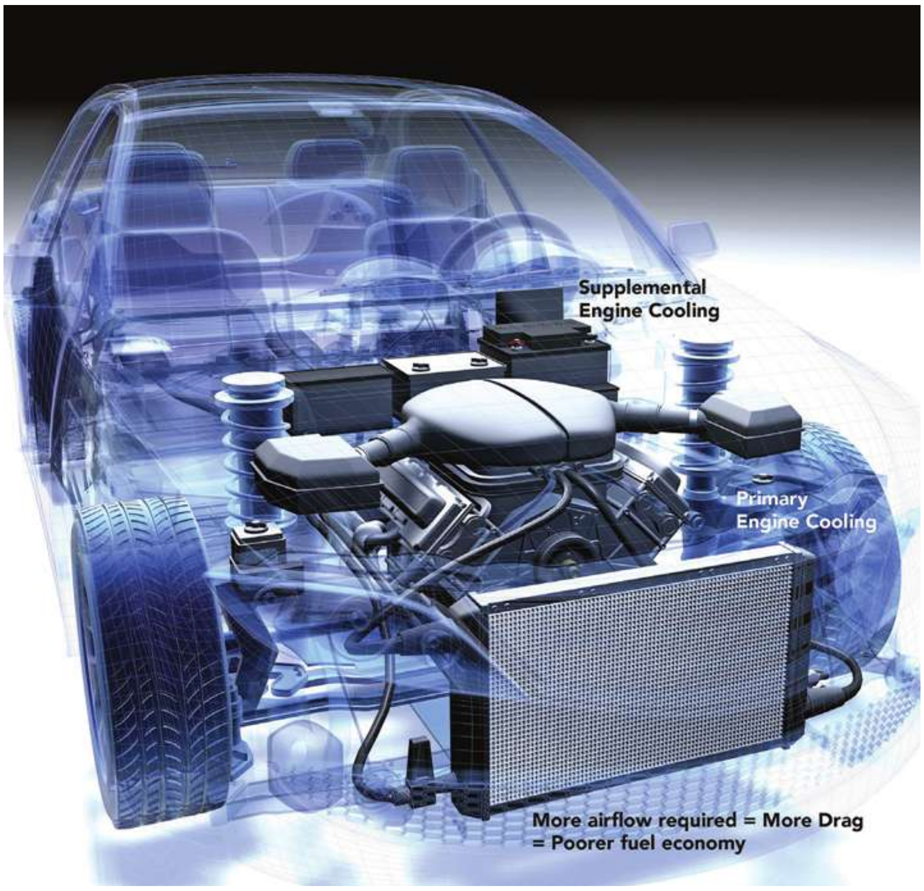
After HIP, parts are either delivered to the customer or, if required, sent out for additional finish machine operations such as grinding, drilling, spot machining, or chemical milling. Delivery time for parts that are HIP, and don't require additional finishing operations after fabrication, is usually three weeks after receipt of order.

In addition to 6Al-4V titanium, CalRAM can also "print" commercially pure titanium, cobalt-chrome steel, gamma titanium aluminide, and nickel-based super alloys including Alloy 625 and Alloy 718. The EBM industry has also conducted fabrication experiments with copper, Invar, and aluminum, so that these materials may be available for EBM fabrication in the future.

Dave Ciscel, Director of Engineering and co-founder of CalRAM Inc., wrote this article for SAE Magazines.

AUTOMOTIVE SIMULATION

Dual-use heater core contributes to better vehicle fuel economy



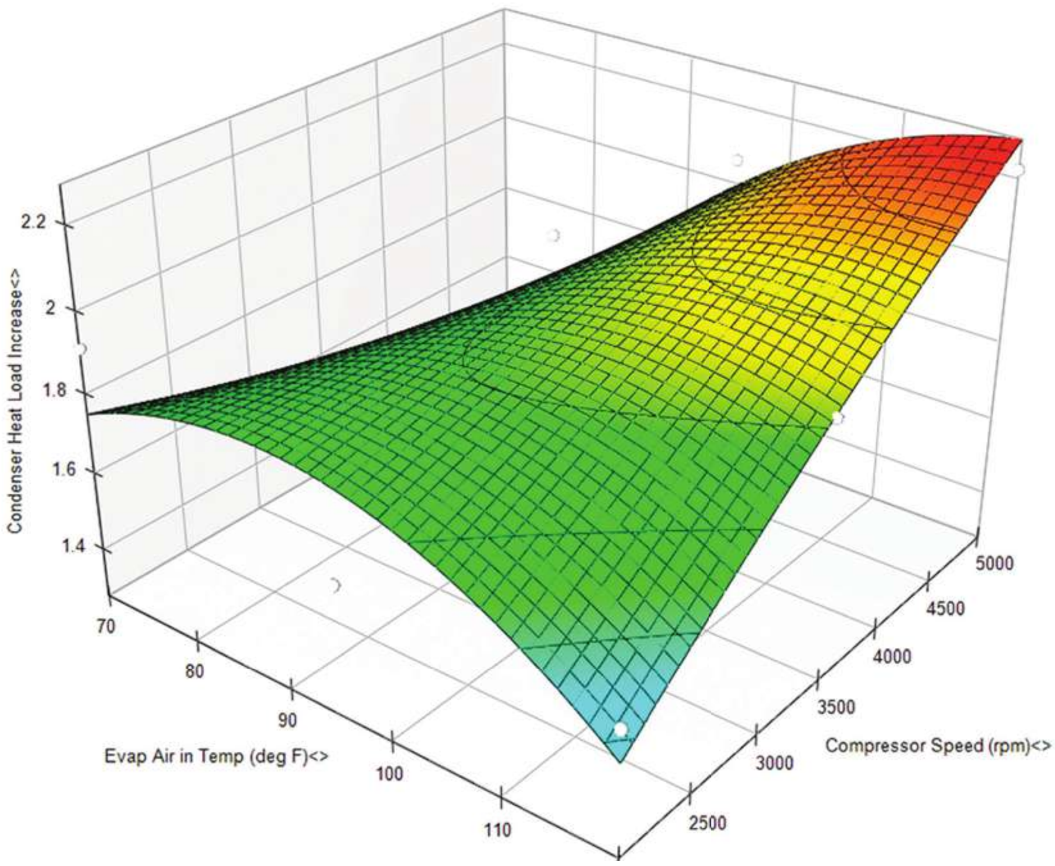
Over-design means an oversized cooling pack and fan that lead to higher drag and lower fuel economy.

Imagine a vehicle towing a 3000-lb (1360-kg) trailer up a 6% grade on a 110°F (43°C) day. This scenario describes less than 1% of driving time, but 100% of vehicles have cooling packs designed around this contingency. This over-design means an oversized cooling pack and fan leading to higher drag and lower fuel economy for the everyday driver. A recent study concluded that a 10% incremental aerodynamic drag reduction gives a 1.5% improvement in vehicle fuel economy for midsize vehicles and 3% improvement in trucks.

CSEG has designed, and filed a patent for, a more elegant solution that would allow for the extreme driving condition scenario while downsizing the cooling pack, increasing fuel economy, and reducing costs for the OEM as well as the customers who do the driving. This design uses an additional vent door in the HVAC airbox in conjunction with the heater core to make better use of existing components, optimizing efficiency.

The heater core is capable of removing 10-20% of total engine waste heat because it is already plumbed into the engine with constant ample coolant flow. The heater core could be used to supplement engine cooling, on-demand, so that the front-end cooling pack can be optimized for regular driving, which would improve fuel economy. The trouble is, when it is hot outside and the engine needs extra cooling, the driver is also hot and unlikely to turn on the heater.

To address this, the HVAC airbox is modified by adding a vent door, called the "cooling door," near the heater core. This cooling door vents hot air from the heater core back out of the cabin so the



Condenser load change and supplemental cooling is enabled.

cabin comfort would not be affected.

During extreme operating conditions and when the driver has A/C on, the blend door would allow some air to go to the heater core while maintaining the cool airflow to the passenger cabin. This diverted airflow passes through the heater core to provide supplemental engine cooling. The cooling door opens, and the hot air from the heater core is vented back into the underhood. The blend door would be positioned such that cabin comfort is not affected. The amount of airflow through the heater core will determine the amount of supplemental engine cooling that the heater core will provide. The blower will need to be operated at a slightly higher speed to deliver enough airflow to the passenger cabin and to the heater core. The cooling door position and the blower speed would be controlled automatically by the ECU depending on the engine cooling and cabin comfort requirements.

When passenger cabin heating is also desired in addition to supplemental engine cooling, the engine cooling door would be positioned such that some of the hot air from the heater core is sent into the passenger cabin and the remaining is vented into the underhood, providing both passenger cabin heating and supplemental engine cooling. When supplemental engine cooling is not desired, the engine cooling door would remain closed, mimicking the HVAC air box operation of today.

The efficacy of this design was computationally evaluated using **Flowmaster**, part of the **Mentor Graphics** Mechanical Analysis Division. For every CFM that was sent through the heater core, there was a 1.5x CFM reduction in required front-end airflow. This was because the heater core operates at a much higher effectiveness than the radiator.

There is another variable to consider. When the A/C is on and additional air is sent through the evaporator, the heat load of the condenser goes up. This, in turn, puts additional heat load on the cooling pack. The effect of the condenser load was evaluated computationally. In one scenario, when additional 150 CFM airflow was sent through the evaporator, the condenser heat load went up by 40%. When additional 200 CFM was sent through the evaporator, the condenser heat load went up by 80%. However, when full simulation was performed to account for this added condenser heat load, there was still a very clear benefit. For every CFM that was sent through the heater core, there was a 1.2x CFM reduction in required front-end airflow.

The key benefit of this technology is an optimized front-end cooling module for everyday driving, leading to better fuel economy. The size of the front-end cooling module and the size of the cooling fan could be reduced. If the front-end cooling module size and architecture were fixed for legacy reasons, then adding this technology would give the vehicle a higher trailer-tow rating because the engine cooling capability has been increased. In addition, this technology enhances the operation and benefits of other fuel-saving technologies such as automatic grille shutters and exhaust gas recirculation by enabling them to operate closer to their optimum efficiency points.

Sudhi Uppuluri, Principal Investigator, Computational Sciences Experts Group (CSEG), wrote this article for SAE Magazines.

SMACing the automotive industry: from concept to consumer

Technology is making a more significant impact on today's auto industry. Perhaps one of the most notable examples is the development of connected technologies coupled with social, mobile, analytics, and cloud (SMAC) technologies.

by Asit K. Barma, Publication Board Chairman, SAEINDIA

Three key technology trends are making significant impacts in the automotive industry today.

The first trend is the adoption of faster and smarter technologies to accelerate product development and reduce costs. Simulation, modeling, and virtualization of product engineering, prototyping, and manufacturing are expected to improve quality, reduce costs, and speed time-to-market from concept to consumer. Several technology companies are pioneering this approach to automotive, aerospace, and discrete manufacturing industries.

Additionally, next-generation vehicle technologies are being explored to optimize fuel consumption and meet regulatory requirements. The hybrid-electric vehicle (HEV) is one such area of research among many others.

Finally, and most significantly, is the development of connected technologies coupled with the Internet Of Things (IOTs), Global Positioning System (GPS), and social, mobile, analytics, and cloud (SMAC) technologies. Moreover, advancements on platforms and devices in terms of intuitive user interfaces, powerful processors, open source mobile platforms, and display technologies are creating a highly favorable ecosystem for integrated in-vehicle solutions. **Ford**'s Sync and **General Motors**' OnStar are a few popular solutions among many others. Recently, the **Cadillac** User Experience (CUE) system, fitted to all current Cadillac models, has emerged as a robust infotainment solution.

Today, the cost of electronics in luxury vehicles is well over 25% of the total manufacturing cost. In the 1970s it was just 2.5%. This cost is expected to go up by over 50% within the next five years. One may be surprised that there are about 10 million lines of code, which drive a luxury automobile. In 1970, it was just 100 lines.

It is also estimated that, on an average, over 80% of the innovation and R&D cost is spent on electronics and embedded systems. Technology companies have never been more involved in automobile technology as they are today. **Google**'s driverless car initiative is well known. So are the similar initiatives from **Microsoft** and many other leading technology companies. **Apple**'s successful patent of in-vehicle dashboard infotainment design is another testimony to this trend.

What makes these technologies very interesting is that they fall at the intersection of four major industry sectors—automotive industry OEMs and suppliers, electronics OEMs, software product development and service companies, and telecom service providers—with each looking to increase sales and drive business.

Google's self-driving car is perhaps the biggest talking point in automotive circles. Having undergone more than 500,000 mi (805,000 km) of testing, it is equipped with four radars, 64 beam lasers on top, GPS, wheel encoders, and safety driver to avoid oncoming traffic, negotiate obstacles, travel pre-set route plans, and thwart potential accident scenarios. Google aims to partner with leading OEMs to provide this as the top technology platform for automobiles.

The automotive sector today has to invest in creating a superior customer experience delivery system. With new-generation technologies like cloud, mobility, social media, and big data, traditional services such as extended warranties, service contracts, and insurance have been replaced with new services like infotainment, loyalty-linked rewards, and promotion.

True to its reputation of always being at the forefront of adopting new technologies and best practices, the automotive sector is all set to create an integrated multi-channel customer experience. For example, in order to take a test-drive of a particular make of vehicle, one just needs to send a Tweet; there is no need to search for the nearest dealer.

Digital strategy for business transformation

Global organizations are embracing digital strategy for their business transformation initiatives. The automotive industry accounts for a significant pie of this investment. Affordable digital initiatives are bringing all players in the automotive industry up to par with each other. OEMs, as well as suppliers in the automotive industry, are adopting SMAC to transform their businesses.

It is important to know how to apply the four SMAC components of social computing, mobility technology, analytics, and the cloud for business transformation—in other words, SMACing the automotive industry.

SMACing powers a company in its digital race to be more customer-centric and more productive with the launch of new products, insights for greater value engineering, reduced vehicle recall cost, and enhanced consumer experience—impacting all key stakeholders in the automotive industry value chain.

The growth in Internet access through mobile devices has fueled the demand for real-time information. Machine-to-machine (M2M) technology further powers this growth, as it enables communication between devices via Internet connections. A portfolio of M2M solutions can be seen in fleet management, asset tracking, and many such applications. Shop floor to top floor applications to integrate shop floor equipment and assembly lines with other business applications and shop floor on mobile devices are some examples.

Creating a community of innovators and design enthusiasts using social media—what can be termed as crowdsourcing of design and innovation—is another example of SMACing. The **BMW Group** and **Local Motors**, for instance, initiated a collaborative design and development project called The Urban Driving Experience Challenge. The challenge asked the Local Motors community of nearly 30,000 designers, engineers, fabricators, and enthusiasts to identify the future premium vehicle features and functions that will define the urban driving experience in the year 2025.

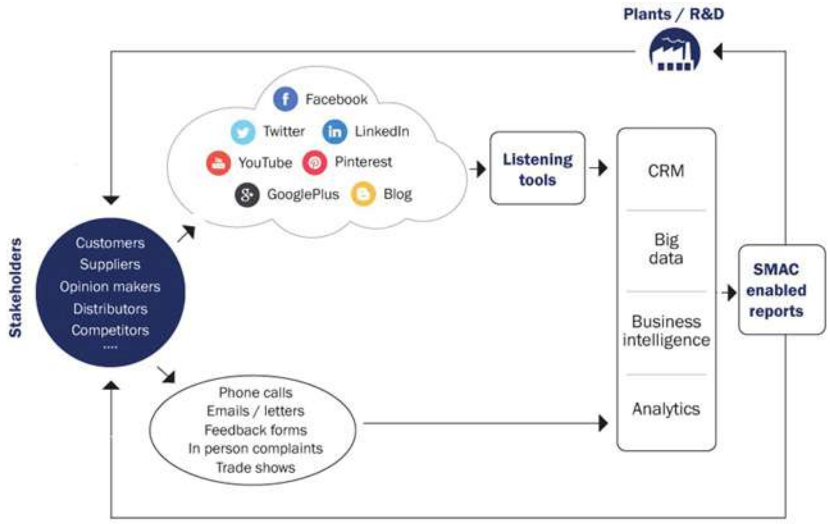


Figure 1. Input from stakeholders including customers, suppliers, opinion makers, distributors, and competitors are captured in real time through social media as well as conventional media and through phone calls, emails, and trade shows.

The three-week competition was held at LocalMotors.com from Sept. 25th through Oct. 16th in 2012. By the end of the challenge period, nearly 3500 individual design boards had been submitted in support of just over 400 innovative feature concepts. After an extensive review and validation process, 286 entries were qualified as having met all specified criteria. A council of 14 BMW Group executives reviewed these entries, and BMW management selected the top 10 concepts. The entries represent a wide range of concepts including interior design, connectivity, the future of car sharing, and the application of new technologies.

Forrester Research, Inc., on July 12, 2013, published an article on how the corporate app store of **China Eastern Airlines** (CEA), one of the top airlines in China, boosts enterprise mobility. CEA estimates that around 50,000 of its employees use mobile devices for work. To support this usage and leverage mobility even further across the enterprise, CEA's IT department developed applications for its workforce and set up a corporate app store to manage access and simplify provisioning. The report highlighted CEA's best practices for operating a corporate app store and securing cooperation from key internal stakeholders to increase mobile engagement for business growth.

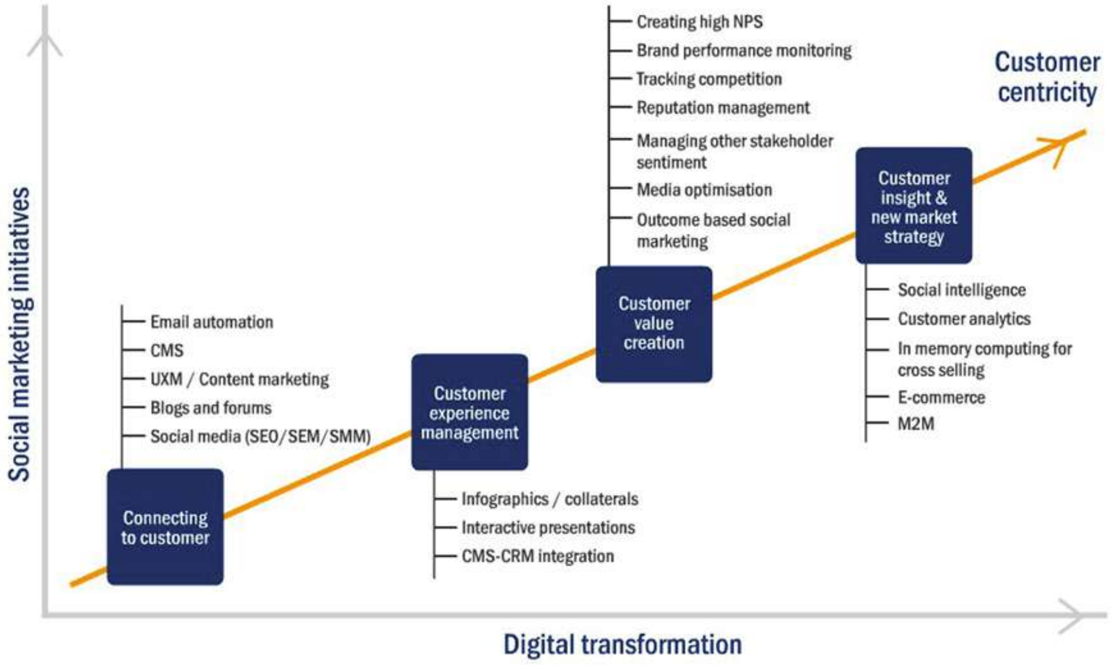
Less than one year after General Motors announced that it would stop outsourcing its IT work to other companies, the company launched a new $130 million data center of its own in mid-2013 using cloud and big-data concepts. The company is betting that a thoroughly modernized approach to IT, consciously modeled in many ways on advances made by Google and **Facebook**, will help accelerate its turnaround.

The company's new data center has been designed to be easier to maintain and expand as well as be less expensive. It also supports a mix of conventional and experimental technologies that the company hopes will measurably improve its capacity to innovate by doubling the number of IT projects it is able to undertake. GM's decision to deploy Big Insights is a big win for **IBM**, which ranks as the number one "big data" vendor by revenue.

'Concept to customer' lifecycle management

Today, automotive OEMs face tremendous challenges from changing customer behaviors, which are influenced by factors like easy availability of credit and the shift of activity to the economies of BRICS (Brazil,

Figure 2. Various social marketing initiatives can enhance a firm's customer-centricity as it progresses on its digital transformation path.



Russia, India, China, and South Africa) countries. OEMs need to innovate constantly in terms of how they manage the portfolio of products and product lifecycles in view of superior customer experience, consumer demand-led product innovation, ever rising competition, quick time-to-market, supply chain management, safety, and environment regulations. Concept to customer lifecycle management was never as challenging as it is today.

New technologies like social, mobility, analytics, and cloud computing can be effectively used by the auto OEMs to respond to modern challenges of developing a vehicle and creating a customer experience around a defined design, targeted cost, and fixed timeline. As discussed earlier, crowdsourcing of product innovations, connected car technologies, shop floor to top floor or digitized manufacturing operations, demography-based product design and marketing, and social listening to capture voice of customer to enhance product quality or improve service delivery are some of the SMAC-driven disruptive practices.

Be a game changer

Automotive companies can respond to market challenges and address the emerging trends by implementing a phased digital business strategy, choosing the right digital technology portfolio across the value chain, and aligning these with the core competencies and chosen strategies of the organization. In a nutshell, automotive companies will be able to stand out in the marketplace if they can create a high level of customer-centricity in their business processes, foster technology-enabled collaboration, and optimize their choice of technologies.

Two diagrams from **ValueLabs** provide a framework to implement the SMAC strategy in the automotive industry (Figure 1) and create greater customer intimacy through social media marketing (Figure 2). Together they result in superior customer experience, product innovations, process improvement, and higher productivity.

In Figure 1, sentiments from all stakeholders including customers, suppliers, opinion makers, distributors, and competitors are captured in real time through social media such as Facebook, Twitter, blogs, as well as conventional media and through phone calls, emails, and trade shows. These signals pass through various proprietary and open-source listening tools prior to being fed to the CRM (customer relationship management) system.

With available business intelligence and analytics tools, meaningful reports can be generated to engage with the stakeholders as well as provide useful information to production and R&D departments. There are instances of many OEMs deciding on the product features for different price ranges and market demography based on stakeholder feedback. This process can also significantly reduce possible vehicle recall costs for which billions of dollars are wasted by the auto OEMs each year.

Figure 2 shows various social marketing initiatives to enhance a firm's customer-centricity as it progresses on its digital transformation path. Social marketing initiatives have been broadly classified into four categories—connecting to customer, customer experience management, customer value creation, and customer insight and new market strategy.

All the players in an automotive-industry value chain can create tremendous business value with simple SMAC applications such as SEO (search engine optimization)/SEM (search engine marketing)/SMM (social media marketing)/blogs/CMS (customer management system)-CRM integration, to the relatively complex ones such as outcome-based social marketing, in-memory computing, M2M, social intelligence, and customer analytics. ■

The 3i paradigm: India's story

The concept of ideation, incubation, and implementation is enhancing the growth of the Indian automotive industry.

by Dr. Arun Jaura

The 3i paradigm is a powerful trident of ideation, incubation, and implementation. It is about steering each of these elements separately and then in unison to connect dots in the growth matrix of an organization for high-throttle traction. Bringing in a strategic mindset change and a synchronization with the organizational culture is the key to the 3i paradigm. During the last decade, the 3i paradigm has enhanced the pace of growth of the automotive industry in India through technologies and varieties of features delivered at an affordable price to customers.

Ideation is the phase in which ideas are solicited, generated, and consolidated—individually or in a group and through open and closed techniques. The Indian automotive industry has intentionally focused increasing amounts of time and energy into the ideation phase. This phase is not solely about products; it involves zeroing down on manufacturing processes as well as all other value-chain services. The canvas of ideation includes zero-based costing, hiring processes, training, joint venture integration, marketing channels, lean manufacturing, automated assembly, virtual engineering, styling, and supply chain. It has cultivated cross-functional participation and an inclusive thought process among stakeholders.

The ideation phase within India has taken into account the importance of intellectual property and its value in opening up avenues for Indian companies globally. Through the ideation phase, processes for documentation and traceability have become more critical and robust to preserve businesses' intellectual properties in India.

In addition to reflecting the innovation index of an organization, intellectual property provides businesses with a supplementary revenue stream in many cases. To bring on this paradigm change, the Indian industry needs to innovate and stay ahead of the curve to fulfill customers' ever-changing aspirations. The mainstream processes must be accelerated for Indian companies to effectively compete globally.

Incubation follows ideation, an interesting on-the-ground artillery phase, in which businesses use resources for pilot launches, sample customer clinics, testing their hypotheses, exploring adaptability and flexibility, and gauging the mindset of stakeholders (consumers, investors, employees, and others). The incubation phase allows companies to gain confidence about the potential success or failure of their ideas for prospective products and services. Furthermore, this is the phase in which organizations evaluate customer interests as well as the extent of their own organization's commitment to prospective ideas or services.

Incubation is a unique phase during which organizations tend to either neglect or overdo activities crucial to the phase in their attempts to get their ideas out into the market place before their competitors. Statistics exemplify this divide as there is a 30/70 ratio of the success/failure rate during the incubation phase. This lopsided ratio is attributed to the lack of talent availability and visibility through processes. Furthermore, companies tend to rush the launch of their products or services at the expense of cross-functional team participation.

The last element of the 3i trident is implementation, which can be considered most crucial to the success of 3i. The preceding two "i"s are intertwined with this phase and feed into this element. A successful implementation is possible through effective program management and stakeholders' commitment to the process. The sub-elements of implementation include

The 3i paradigm: India's story

the scalability of the incubated idea, flexibility, resourcing, the ramp-up of supply chain, risk management, and mitigation. Organizations tend to overlook such aspects during implementation and end up with a larger life-support system for periods that extend beyond the launches of their products. Statistics show that a clean implementation can save an organization seven to eight times the cost and five times the development time to fix it.

With the changing 3i paradigm, implementation has become more integrated in program management. Planning and strategy are more robust, and teams are better prepared to pre-empt the issues. With the presence of global automotive manufacturers' in India, the perspectives and learnings have percolated deeper into Indian organizations. Furthermore, the Indian industry has been able to deploy products and services at a greater speed due to lower volumes as compared to other global players. The cost impact can be spread and is not very harsh to the customer. Some regulations coming into India have yet to catch up with the global norms so the content, developmental resources, and operational issues are lessened. This has resulted in lesser cost and wider mass market outreach in the country.

With cross-border acquisitions growing, Indian organizations have noticed a sudden growth in their access to technology and penetration possibilities into different markets. During the integration phase of old and newly acquired organizations, distribution and decision making in different domains of an organization allow for an excellent opportunity for the deployment of the 3i paradigm.

To harness these changing dynamics, a recent trend in the automotive fraternity has gained traction, the appointment of group chief technology officers. CTOs oversee technologies at the group level, create synergies, develop technology strategies, and are advocates for innovation across organizations, thus making them core catalysts to the 3i paradigm.

Through public private partnerships (PPPs) and directed basic research, consortiums have been able to attract stakeholders, thus allowing for the distribution of ideas and technologies, which is the underlying purpose of the 3i paradigm.

The government of India has set up a National Mission on Manufacturing Excellence for clean, green manufacturing, and building the ecosphere through PPP. The government recently set up the National Mission on Electric Mobility to attract stakeholders to facilitate the growth of e-mobility and out-of-the-box thinking. There were other missions and policies rolled out by the government such as the Automotive Mission Plan, National Fuel Policy, National Hybrid Propulsion Program, and regulations for stricter emission norms, vehicle and occupant safety, and end-of-life of vehicles. These PPPs and policies are enablers of 3i in the industry to build the larger socio-economic base and have also provided mobility of skill sets and ideas between vendors, OEMs, research laboratories, and academia.

Dr. Arun Jaura, MD & Founder, TRAKTION Management Services Pvt Ltd, is on the Board of Directors of SAE International, and is Chairman, Automotive Board, SAEINDIA.

The 3i focus in consortia has strengthened academia-industry partnerships in the development of current and advanced products for applications that have a direct business impact. The talent pipeline and utilization ratios of equipment in laboratories have grown and the training and development of staff, students, and skilled workers received an impetus through the huge funding of the National Skill Development Council (NSDC). The NSDC has set up different industry working boards, the automotive industry included, to increase the demand for skill development of blue-collared workers, sales and marketing, and the engineering and technology workforce.

Another recent development in India is the ability to access patents in an online repository and the filing of online patent applications. The policy of "right of first filing" has helped inventors protect their ideas and innovations for their respective organizations. The Ministry of Commerce and Industry (Department of Industry Policy and Promotion) issued patent amendment rules through gazettes published in 2013 and 2014 carrying guidelines on government support and incentives for employees and organizations for filing patent applications. The government also published the rules in Hindi to ensure widespread publicity in the industries and to individual inventors across the country.

It is prudent that an organization have patience to allow 3i to grow as it is crucial to generating sustained revenue. An incomplete implementation of an incubated idea results in erosion of the organization's reputation and an unnecessary waste of resources.

Strategically driving the 3i paradigm creates a vibrant consumer culture, boosts employee morale, and leads to increased investment by businesses for organic growth. A faster shift to the 3i paradigm will continue to be crucial for the Indian automotive industry since nothing is better than the taste of a successful launch—process, product, or a service. ■

Virtualization for automotive IVI systems

As the demand for modern in-vehicle infotainment systems grows, automakers are increasingly looking toward virtualization as a solution to bridge the gap between consumer and automotive electronics.

by V. Saminathan and G. Swaminathan

In the past, automotive audio systems were characterized by simple functionality, a simple tuner, minimal user interface, and little to no two-way communication channels. They were also closed, in the sense that all of the software was loaded pre-sale by the manufacturer and normally remained unchanged for the lifetime of the device. The amount of software was small.

Many modern in-vehicle infotainment (IVI) systems, however, are very different. Today's systems have sophisticated user interfaces, consisting of input keys or a touch screen, rearview cameras, audio, and high-resolution video outputs. Additionally, they combine many functions, including voice and data communication, productivity tools, media players, and games. They also support different wireless communication modes, including Wi-Fi, Bluetooth, and infrared. Finally, they allow users to load data and even application programs or "apps." The total amount of software running on today's devices is complex and large, measuring into the millions of lines of code.

Need for virtualization

The gap between consumer electronics and automotive electronics started growing wider because of the rapid consumer adoption of smartphones during the early 2010s. Consumers expect to do everything in their car that they do on their mobile devices—including seamless connectivity to the external world. The automotive industry was conservative for many reasons during the past, but now it must try to bridge the gap between consumers' expectations for infotainment features and the current performance of today's automotive electronics.

The key problems faced by automakers with respect to IVI electronics are:

- Firmware updates: IVI feature sets are rapidly outdated when compared to consumer electronics products
- In-vehicle security: IVI becomes the gateway for the in-vehicle network, which triggers the need for a firewall between the in-vehicle network and the outside world.

To address the above problems, "sandboxing" (virtualization) is emerging as a key solution.

The concept of virtualization originated in mainframes and is used extensively in the personal computer domain. It has recently picked up in the embedded electronics world, as well.

There are three different types of virtualization techniques:

- Virtual machines: In a virtual machine (VM), the hypervisors run on top of the host operating-system environment. With the hypervisor layer as a distinct second software level, guest operating systems run at the third level above the hardware. (Examples: **VMware** products, **Oracle** VirtualBox, QEMU)
- Para-virtualization or bare-metal virtualization: With para-virtualization, the hypervisors run directly on the host's hardware to both control the hardware and manage guest operating systems. A guest operating system runs on another level above the hypervisor. (Example: COQOS from **OpenSynergy**)
- Containers virtualization: A method where the kernel of an operating system allows for multiple isolated user-space instances, instead of just one. Virtualization techniques each have their own advantages and disadvantages, although para-virtualization is the most widely technique used on automotive embedded platforms today.

Virtualization benefits

The two primary benefits of virtualization are related to firmware updates and in-vehicle security.

Firmware updates: Virtualization has opened new doors when it comes to IVI design techniques. Using virtualization, an IVI architecture can be separated into critical and non-critical partitions. The critical partition takes care of vehicle network communication and other critical software that requires an RTOS (real-time operating system) or thin OS. On the other hand, media, connectivity, voice features, and other UI-related features are

Guest Application	Guest Application	Guest Application
Guest Operating System		
Virtual-Machine Monitor (VMM)		
Host Operating System		
Host Hardware		

Virtual Machines are one of three types of virtualization techniques.

Guest Application	Guest Application	Guest Application
Guest Operating System		
Virtual-Machine Monitor (VMM)		
Host Hardware		

Para-Virtualization is another widely used technique.

Guest Application	Guest Application	Guest Application
Guest OS & Root File System	Guest OS & Root File System	Guest OS & Root File System
Shared Kernel		
Host Operating System		
Host Hardware		

In Containers Virtualization, the kernel of an operating system allows for multiple isolated user-space instances.

placed in the non-critical partition. This partition runs on a high-end, consumer-based OS such as Linux or Android. This architecture also makes it possible for the firmware of one partition to be updated without affecting the other partition. This benefits OEMs by enabling them to keep the non-critical (application) partition up-to-date without affecting the critical partition.

In-vehicle security: Virtualization can be used to enhance security. A virtual machine encapsulates a subsystem so that its failure cannot interfere with other subsystems. In an IVI, for example, the in-vehicle CAN (controller area network) communication stack is of critical importance. If the stack were subverted by an attacker, the IVI could interfere with other critical CAN nodes in the vehicle network. In an extreme case, the vehicle network could be compromised, which could result in a vehicle becoming stranded in the middle of the road. Similarly, an encryption subsystem needs to be strongly shielded from potential threats so that sensitive user and vehicle information can be protected from hackers. This is a significant challenge for a system running millions of lines of code, many of which are security-critical. The high-level OS is particularly vulnerable to attacks in open systems (which allow owners to download and run arbitrary programs), and is large enough to contain hundreds or thousands of bugs. In the absence of virtualization, the high-level OS runs in "privileged mode," which means that, once compromised, it can attack any part of the system. With virtualization, the high-level OS is "de-privileged" and unable to interfere with data belonging to other subsystems. Additionally, its access to the processor can be limited to ensure that critical components are not compromised by bugs or other unscrupulous code.

Limits of virtualization

Virtualization has its limits related to software complexity, integration, security policies, and trusted computing base.

V. Saminathan, Visteon Electronics Innovation Head, India.

G. Swaminathan, Visteon Electronics, India.

Software complexity: The isolation provided by virtualization creates a complete machine for each subsystem. This means that each virtual machine has to run its own operating system, making it relatively "heavy" when it comes to software code. Increasing the number of virtual machines (to reduce the granularity of the subsystems) could create serious performance issues and significantly increase the amount of code. This not only requires increased memory size, but also introduces more potential points of failure.

Integration: The subsystems of an embedded system are not independent. They need to be designed to cooperate closely to achieve the intended functionality of the system.

Security policies: Many embedded systems must meet critical security requirements. Virtualization alone does not necessarily help address all of these requirements.

Trusted computing base: Virtualization does not support minimizing the trusted computing base (TCB). The TCB frequently has high performance requirements, meaning that it must be able to communicate efficiently with the rest of the system. Virtualization does not serve this requirement.

Conclusions

For the **ARM** Cortex-A9 processor, para-virtualization is generally seen as the best option in the embedded domain. Similarly, for the Cortex-A15 processor, a thin, para-virtualized hypervisor can continue to serve as the foundation for embedded IVI systems, performing resource management (memory, devices, energy, and global scheduling) and facilitating secure communication and resource sharing among guest operating systems.

On the other hand, ARM's A15 core also comes with hypervisor mode, which enables hardware-assisted virtualization. Focusing on this strategy, para-virtualization suppliers such as OpenSynergy are also extending their hypervisor mode to accommodate ARM Cortex-A15 processor capabilities, including hardware-assisted virtualization, 40-bit addressing, and the latest ARMv7-A instruction set. Hardware-assisted virtualization reduces the maintenance overhead of para-virtualization, as it reduces the changes needed in the guest operating system.

Going forward, these types of virtualization architectures are poised to provide the best options for designing world-class software for tomorrow's connected vehicles. ■

Command Center: Securing connected cars of the future

An architectural approach to minimize connectivity interfaces acts as a secure, intelligent gateway between the car and external devices/networks to better guard against malicious or sensitive data from being compromised.

Gone are the days when cars were only used to commute and had a radio or a CD player in the name of multimedia. Today's cars have the capability to be connected to devices both inside the car and on the Internet. They typically have 50-70 electronic control units (ECUs) running various functions and providing comfort, reliability, and safety. It is also now possible to stream personalized content via the Internet, keep in touch with friends, and shop online—all from inside the car.

This advancement does not come without its can of worms; a connected car directly or indirectly linked to the Internet comes with the high risk of malware attacks in the form of malicious code or data. A malware attack could force a vehicle to behave not as intended, experiencing sudden braking, door opening, or failing of critical safety systems such as airbags.

Carmakers are fully aware of these threats and are finding ways to identify, prevent, and resolve them. One way of addressing this would be by building a sound architecture and methodologies.

Connectivity paradigms

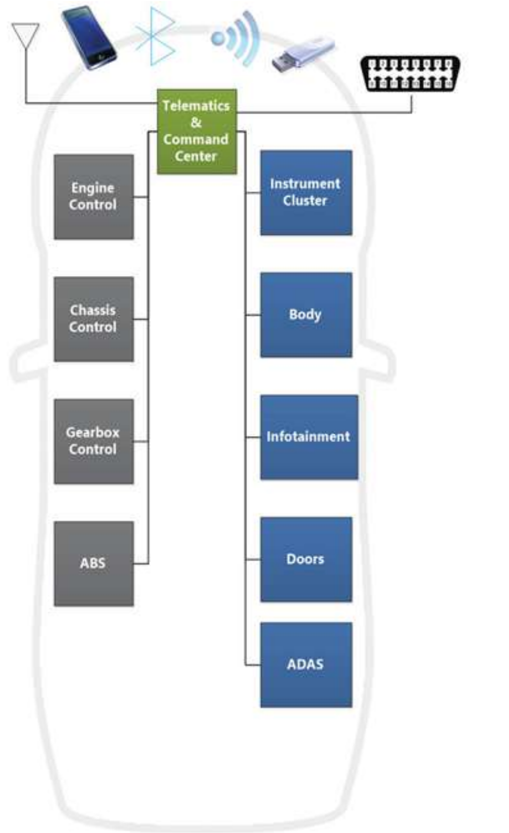
Traditionally car networks were confined to ECUs inside the car, which were connected with automotive networks such as controller area network (CAN), FlexRay, and local interconnect network (LIN). However, cars today are connected to devices and carmakers' portals that provide features like e-Call, remote diagnostics, and data exchange to and from a car. Cars of the future will go one step forward and connect to other cars and exchange data about the operating environment.

Data intensity in modern cars

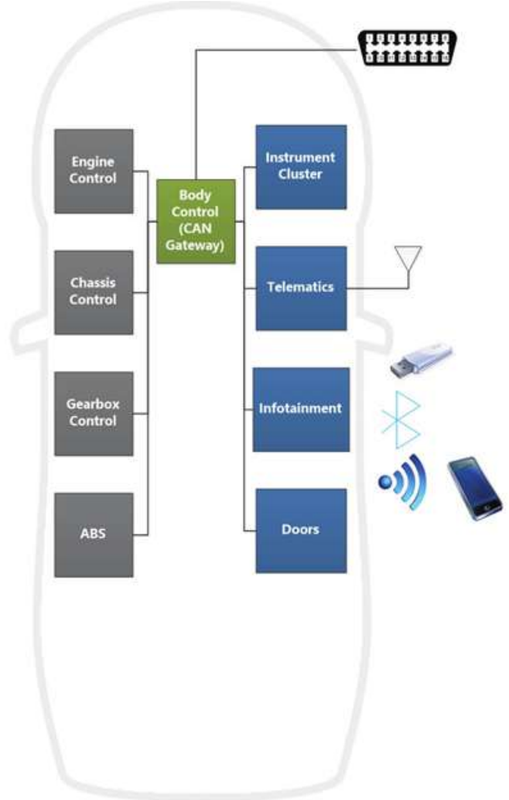
With advancements in infotainment and connectivity, the data intensity of cars has dramatically changed in terms of nature, quantity, and directionality.

These data can be split into the following categories:

• Data inhaled: Data received by the car from the environment via sensors or the Internet. Traditionally, automotive software was concerned only with data received by an ECU via sensors or other ECUs. ECUs, however, may not have been designed to examine every CAN packet received. This risk is further accentuated as inhaled data include data

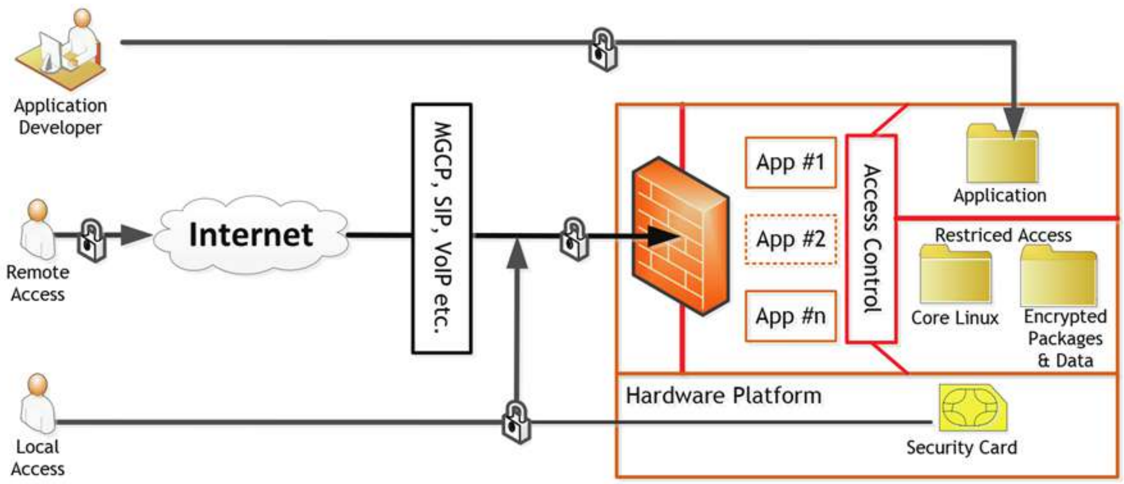


Consolidated connectivity – Command Center Architecture



De-centralized connectivity – Traditional Architecture

The Command Center architectural approach can guard against malicious or sensitive data from being inhaled or exhaled, respectively.



The Command Center can implement various strategies to handle security risks.

from the cloud or data that could be injected into the car network using malicious software sitting on the connectivity interface

• Data processed: Data that goes into various computations on ECUs or user data churned on infotainment ECU. Since the inhaled data may be unsafe, it may lead to errors in data processing. Telematics and infotainment are vulnerable to code tampering and user data manipulation

• Data exhaled: Car and driver behavior data that may be processed in the cloud to deliver a variety of services including customized insurance solutions, targeted content, and advertisements.

Potential risks

As cars are getting connected, both to devices and the external world, the nature and threat of security risks are also changing. For instance, cars interact with the environment through sensors and actuators. Therefore, car security needs to consider security of data and the environment around the car. Also, prevention and real-time detection of security threats needs to be given more importance.

These potential risks can be divided into the following categories:

• Safety: Security vulnerability leads to compromised safety of critical systems, putting the occupants, those outside, and the environment at risk

• Nuisance: Affected non-safety-critical systems could cause cars to deny services or perform undesirable operations

• Privacy: Vulnerability could expose personal information that may be misused or manipulated

• Financial: Financial loss in the form of warranty manipulation or extortion.

Architecture options

Security vulnerabilities increase with an increase in interfaces that enable cars to connect to devices or external networks. One key architectural approach is to minimize the interfaces and consolidate those into a "Command Center," which would act as a secure, intelligent gateway between the car network and the external devices or networks. The approach can better guard against malicious or sensitive data from being inhaled or exhaled, respectively.

The Command Center scheme can include various strategies to handle security risks such as implementing a firewall to provide secure access to the rest of the network.

The following are the key elements of such an approach:

• Protected key entry points: connectivity based on wired and wireless interfaces

• A "closed system": pre-configured firewall providing restricted access

• Fine-grained user access control: near zero lifespan for elevated privileges.

The methodology

A sound engineering approach is also crucial to mitigate security risks at every step of system design. Carmakers and others can consider the following engineering methodologies and design steps to ensure secure connectivity:

• Interface risk analysis

• Functional safety analysis

• Defensive programming.

Interface risk analysis

The process of interface risk analysis includes looking at every system interface involved in connecting a car to a device or cloud. The first step is identifying all interface end points including network end points, device and wireless interfaces, as well as bus connectors. The second and third steps identify the attacks and potential security issues arising out of these attacks, respectively. Once interfaces have been analyzed, appropriate design strategies can be applied.

Functional safety analysis

ISO 26262 provides methods to realize the safety requirements within the system or subsystem. It describes safety analysis methods like

From left: KPIT's Ravi Pandit, Chairman & Group CEO, and Omkar Panse, AVP, Infotainment Practice.

Hazard Analysis and Risk Assessment, Failure Mode Effect Analysis, Fault Tree Analysis, and Criticality Analysis.

The automotive industry should adopt functional safety concepts to assess security analysis. On completion of safety implementation, a safety case with an argumentation is built, which is supported with evidence and demonstrates system safety. This can be extended to security, and such "security cases" could include:

- Evidence about security behavior
- Identification and analysis of hazards, threats, and vulnerabilities
- Compliance to security standards.

Defensive programming

Defensive programming is a practice followed in safety-critical embedded systems. It ensures continuing function of software even during unforeseen usages. In a security context, such unforeseen usage may be because of manipulated data coming from sensors or car networks. Certain principles of defensive programming, such as "all data is tainted until proven otherwise," are powerful means of avoiding software malfunction even in the case of malicious input.

Putting it all together

Modern cars will continue to be increasingly connected and exchange data. However, to make cars impervious to cyber attacks, a vehicle's security architecture needs to be fortified. Command Center and robust engineering methodologies will make this possible. ■

This article was written for SAE Magazines by KPIT's Ravi Pandit, Chairman & Group CEO, and Omkar Panse, AVP, Infotainment Practice.

A new formula for racing

The new series' electric racecars are intended to pioneer new technology for broader use in production, encouraging fans to think differently about the technologies they use.

by Dan Carney

The Spark-Renault SRT_01E, with its aerodynamic shrouds ahead of its wheels, strongly resembles the current Indycar, which is also built by Dallara.

On a global scale, racecars burn an irrelevant amount of fuel, so racing series' interest in fuel-saving technology has nothing to do with saving the planet from racecars' environmental impact.

Transporting teams to the tracks burns far more fossil fuels than any fuel actually consumed at the track. In fact, transporting sports teams of any sort by air to distant competitions burns more fuel than cars competing in a race will use.

Consider the example of race drivers wearing seatbelts encouraging skeptical people to consider wearing belts in their own cars. Or the winning diesel-powered racers at Le Mans helping boost the image of diesel cars that were widely considered sluggish and dull.

So it is meant to be with Formula E: sleek open-wheel racers slicing through the streets of 10 glamorous cities worldwide, putting lie to the notion that EVs are boring transportation modules for people who hate cars.

"We expect this championship to become the framework for research and development around the electric car, a key element for the future of our cities," explained Alejandro Agag, CEO of **Formula E Holdings**. "We have done research that shows that people watching a championship of electric cars will be more inclined to buy electric cars."

So battery-electric racers such as those used in the new Formula E racing series will not make a difference in the planet's ecological balance. But that isn't their purpose. Racecars pioneer new technology for broader use in production, and they serve as thought leaders, encouraging fans to think differently about the technologies they use.

To minimize conflict with existing series and to take advantage of a global scope that means it is always summer somewhere, the series' season will commence Sept. 13 with a race in Beijing and conclude June 27 in London. Between, it will visit Putrajaya, Malaysia; Rio de Janeiro; Punta del Esta, Uruguay; Buenos Aires; Los Angeles; Miami; Monte Carlo; and Berlin. All of these will be conducted on city streets rather than on dedicated circuits.

Because racing EVs struggle with the same issue of battery capacity as conventional EVs, the series will start with 1-h races. Even that is too long for today's batteries, when driven at race pace, so drivers will pit midway through the race and jump into a waiting fully charged car to continue.

So each of the 10 teams entered in the series will have four cars, two for each driver to use during each race.

The cars

Those cars will be Spark-Renault SRT_01E single-seaters built using a carbon-fiber and aluminum monocoque chassis provided by Italian **Indycar** constructor **Dallara**, with assembly and drivetrain integration by **Spark Racing Technology** in France. They are constructed to pass the 2014 **FIA** crash tests applied to **Formula One** cars.

Speaking of Formula One, the electric powertrain and control electronics as well as data logging systems come from **McLaren Electronic Systems**, and the lithium-polymer batteries come from **Williams Advanced Engineering**, both subsidiaries of well-known Formula One teams. The sequential gearbox is


Formula E CEO Alejandro Agag predicts the Formula E series will drive fan interest in buying electric cars.

provided by longtime Formula One supplier **Hewland Engineering**, and its ratios are fixed for the season, so there will be no changing ratios by teams to suit each circuit.

Esteemed racing constructor Dallara built the carbon fiber chassis using know-how earned from building cars for Formula One, Indycar, **Le Mans**, and other venues over the decades.

"We have designed the structure of the car, which means, starting from the front, the nose, front wing main plane, monocoque, safety structure—survival cell, battery box, bellhousing between battery box and gearbox, and everything inside the monocoque—the pedals, steering system, and uprights of the suspension," said Luca Pignacca, Dallara Chief of Design.

The company did this in consultation with Spark, which has integrated the various components into working racecars, he added. "It has been a co-design. We have been working as a team."

When the components arrive in France at Spark's headquarters, **Renault Sport** taps that company's EV experience to help them work together on "the architecture of the electronic system, the reliability, the safety," said Patrice Ratti, Director of Renault Sport Technology. "We are helping with the design and the integration of all of the elements."

While the series initially specifies only the SRT_01E, eventually teams will be able to build their cars in search of a performance advantage.


With its controller atop the electric motor, the McLaren powertrain resembles that of a conventional formula car with an inline engine.

Mahindra Racing is the eighth and only Indian team to race in Formula E.

The powertrain

McLaren provides the Formula E electric motor and its control systems, putting it at the heart of the car's difference from ICE-powered racers. It is an evolution of the 130-kW electric motor the company uses as a hybrid-electric motor in its P1 super sports car. In the SRT_01E, the electric motor's output is limited by the allowable energy from the battery, which is 200 kW, giving the Formula E racers power that is comparable to that of Formula 3 racers.

It can work at this higher output level because the duty cycle of a racing component is shorter and the service environment is less punishing than road service, explained Peter Van Manen, Managing Director of McLaren Electronic Systems.

In the SRT_01E, the electric motor is optimized to run between 13,000 and 18,000 rpm because of the use of the five-speed Hewland gearbox, an unusual feature for an EV. Most EVs connect their electric motor directly to the wheels, but the racecar's broad dynamic range and the benefit of tuning the motor's output for a narrow range made using a gearbox appealing for this car, Van Manen explained.

Test driver Jarno Trulli reports that while the SRT_01E sounds different to observers, from inside the cockpit it performs in a familiar way.

The Hewland gearbox incorporates mounting points for the rear crash impact absorbing structure. (Dan Carney)

The treaded, low-profile, 18-in Michelin racing tires represent many new challenges for an open-wheel racing tire. (Dan Carney)

As the early astronauts had to learn techniques to deal with the near-infinite inertia of zero-gravity, so McLaren engineers have had to learn techniques to deal with the near-zero inertia of the electric motor.

"The biggest thing for us has been not having the inertia you get having an IC flywheel," said Van Manen. "It is electric; as soon as you ask something to happen, it happens," he said. "There is no inertia to smooth it out."

When does this matter? "Every time you change gears. A gear change on a racing car is quite a dramatic event—it is a jolt that you get," Van Manen explained. "Without the inertia, you have to deal with that in software how you control the motor to get a decent shift and not end up with a lot of ringing around the gearbox."

It isn't just when the driver changes gears that lack of inertia is an issue. "Any transients, so every time you put your foot on the accelerator," he said.

McLaren engineers tuned the control software to compensate for this, but it is an area where they had no experience. "A lot of areas where your knowledge and experience is with an IC car, you have to part with that," Van Manen explained. "Engineering is the most fun when you have to tackle problems."

Rules dictate that the cars can run at a maximum of 200 kW of power during practice and qualifying sessions. In races, they'll be limited to 133 kW, with a limited amount of "push-to-pass" mode that releases the full 200 kW of power for brief periods. The resulting top speed is limited by rule to 225 km/h (140 mph).

Hewland Engineering's five-speed gearbox was specifically designed for the SRT_01E, but which naturally employs many components shared with existing models in the company's line, according to a spokesman.

It uses a pneumatic paddle shift system, and because the electric motor can reverse its direction, the gearbox carries no reverse gear. The transmission was optimized for durability, with high rpm and high torque in mind. The casing is magnesium and incorporates attachment points for wheel tethers and rear crash structure.

Energy source

Power comes from a Williams-supplied 200-kg (440-lb) 28-kW·h lithium-polymer battery pack providing the 200 kW of available power. The pack dimensions were coordinated with Dallara to fit in the car inside a protective case that provides physical protection from intrusion along with thermal and electrical isolation from the rest of the car.

The lithium-polymer pouch cells are cooled by liquid, and their individual voltage and temperature are watched by cell-monitoring units (CMUs). Those CMUs in turn report their information to the battery management system (BMS) via the car's CAN bus. The BMS controls state of charge, charge/discharge power limits, cell state of charge balancing, isolation monitoring, and other factors. Maximum bus voltage is 1000 V.

The BMS and CMUs were both developed in 2009 for the Williams Formula One program when that series began using hybrid-electric power. Another potentially overlooked specification of the battery pack is that, because the Formula E series is global and transports its cars to races using air freight, the battery pack is certified for safe air transportation.

Rubber meets the road

O.Z. Racing provides the 18-in wheels. The tires are treaded **Michelin**s that probably bear stronger similarity to the company's sports car racing tires than to the ones the company used to supply for Formula One, because of that series' unique use of 13-in wheels and high-profile tires rather than the larger wheels and low-profile tires used elsewhere.

The treaded tires use a compound hard enough that the cars each use a single set of new tires for the race; a set of used tires may be used for practice and qualifying. Using treaded tires means teams won't have to stop the cars to switch from slicks if it starts raining during races. In fact, pit stops for tire changes during races aren't permitted in Formula E, saving teams the expense of pit stop equipment and manpower.

"This tire must have a compromise of running low temperatures, running high temperatures, different concrete, tarmac, pavement, rain, dry, so it will be a much more complete and much more complex tire to develop," observed Lucas di Grassi, Formula E development driver.

As if that weren't challenge enough, the series has also specified that the tires be 18-in low-profile tires, in the manner of popular street types.

"For the first time in a single-seater racecar, you will see 18-inch tire diameter," noted Florent Menegaux, President of Michelin's car and light truck product line

These tires will have reduced rolling resistance compared to the traditional type, boosting efficiency, he said. "Fuel efficiency in an electric car translates into additional power or additional [driving] time," he added. That

Drayson Racing Chief Engineer Graham Moore enjoys the benefit of experience with the team's electric land speed record car as it prepares its cars for Formula E competition.

may well be, but it presents one of the many challenges faced by teams aiming to win races in this new series.

On track challenges

"They've gone from a 13-inch, which is typical for a formula car, to an 18-inch low-profile rubber," said Graham Moore, Chief Engineer for **Drayson Racing Technologies**.

"That's going to be interesting, because street circuits are normally quite bumpy, so the last thing you normally want is a low-profile tire, because it's going to give some interesting inputs into the chassis."

All of the series' races are planned for street circuits, with the idea being that electric cars can run in city centers, in front of large crowds, without offending anyone with their noise.

"In F1 for example, a lot of the suspension deflection is done in the tire [side] wall, but we don't have that with a very low-profile tire, so that's all going straight into the suspension," Moore said. "Street circuits are notoriously bumpy, slippery, and have a lot of camber changes. The cars are going to be quite a handful with no traction control."

Drayson Racing Technologies is a British team entered in the series that already has extensive high-performance EV experience as the recent electric-powered world speed record holder. In October 2013, the team set a world speed record for electric cars weighing less than 999 kg, averaging 205 mph over 1 mi (1.6 km) with a flying start and running once in each direction to equalize for wind and elevation changes.

The team is in the enviable position of being able to simulate the Formula E to some degree using its speed record car, despite their differences, according to Moore. But there is no substitute for testing the real thing when it comes to devising race strategies.

"Once we've got a few tests out of the way, we'll know how far we can go and how much we can push the car and for how long—and therefore know its operating envelope and strategy," Moore explained. That will mean, of course, that the teams are finally really racing, rather than simply demonstrating technology. That development should help overcome concerns about the EV's lack of exhaust note on the track.

"You have a constant debate about electric vehicles and noise. People say there won't be any noise and it will be terrible. But noise is a waste of energy," said Moore. "It will be a different noise. And Formula E shouldn't replicate the noise of a petrol engine—you don't want that noise, especially in a city center environment." ■

Driving good dynamics

How the demands of safety, light weight, ride, and handling can be brought together to create cars of character.

Dave Rollett, Vehicle Dynamics Team Leader at motorsport and engineering consultancy **Prodrive**, is forthright in his views about car buyers: "Most do not know what good dynamics feel like, yet they form strong opinions about a vehicle based on how the dynamics feel to themselves."

Because dynamics are a vital part of brand identity creation, getting them right from both engineering and customer standpoints is a must.

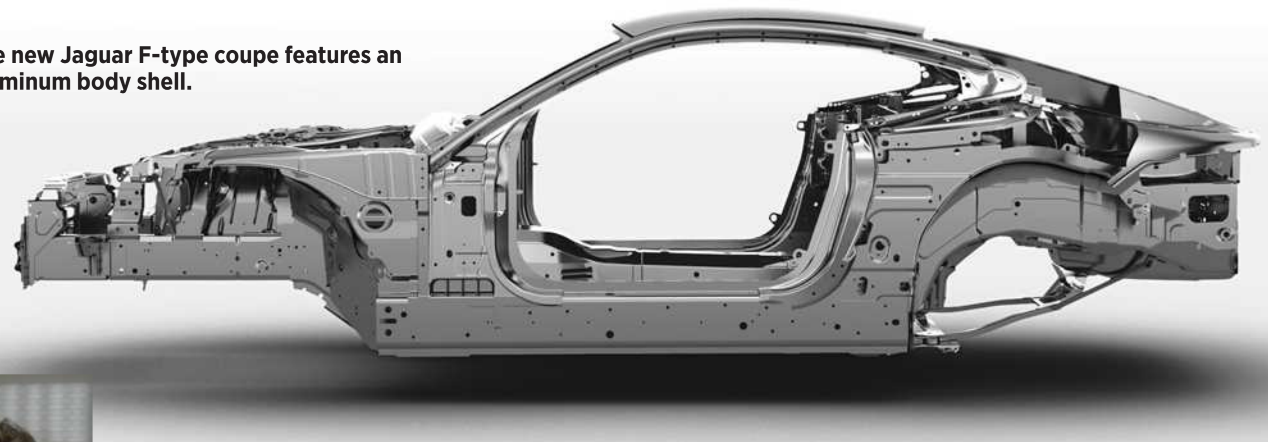
"Modern cars rarely suffer from poor chassis dynamics, but they may reach the market with inappropriate dynamics," Rollett said. "The key for a dynamicist today is to understand how the driver uses dynamic feel to interpret the vehicle brand."

Brand identity through dynamics is not new, but it is ever more important in a world that is seeing increasing use of multi-role modular chassis designs such as the **Volkswagen** Group's MQB modular platform.

A member of that Group is Spanish company **SEAT**, which has worked to create a "sporting" image based on "character" for its products; it uses the MQB to good effect.

"Here at SEAT, we are Spanish and we are German," said Executive Vice President for Research and Development, Dr. Matthias Rabe. "Thanks to the flexibility of the MQB, SEAT has developed the Leon family according to its own DNA, target customers, and marketing positioning."

The new Jaguar F-type coupe is all about efficient dynamics.



The new Jaguar F-type coupe features an aluminum body shell.

JLR's Dr. Wolfgang Ziebart is very cautious about the use of carbon fiber.

More modular solutions

Mercedes-Benz also applies modular chassis solutions. These include the MRA (rear-drive architecture), which it uses for the latest C-Class (previously described by *Automotive Engineering* at http://articles.sae.org/12683 and at http://articles.sae.org/12983).

It has taken some five years to fully develop the new-generation architecture. The company's most flexible, it can be tailored for use by many classes of car, said Dr. Michael Krämer, Vice President–Program Management: "We had a very important concept phase with everybody from engineering to marketing discussing the right strategic guidelines. **AMG** was at the table, too. So the suspension design was decided as a team effort, and our production colleagues were there to work out how we were going to build it."

The result is a C-Class that provides a comprehensive ride-and-handling solution created to take the C-Class into a new dynamics and quality segment. Air suspension is an option, a claimed "first" in its class, and the driver has a wide selection of chassis response settings including an extra bespoke "Individual" mode.

Said Krämer: "The biggest design challenge was predicting the future; this architecture needs to keep going for many years, so it is flexible—like a tool kit. If drivers have tough days they may wish for light steering and a soft ride to soothe them, but for driving hard it's a firmer ride and more direct steering that's wanted. It's all about choice."

Complementing this is a switch to more intensive use of aluminum for the body structure. The new C-Class body-in-white is some 70 kg (154 lb) lighter than that of the previous generation, and total weight savings on the car reaches 100 kg (220 lb).

Saving 400 kg

The use of aluminum is a "very, very strong contributor" to the enhancement of dynamics, according to **Jaguar Land Rover** (JLR) Engineering Director Dr. Wolfgang Ziebart: "We see that in the Range Rover and in **Jaguar** sports cars. In the case of the Range Rover we have saved 400 kg; just imagine how the vehicle would drive with close to half a ton onboard!"

But intensive use of aluminum is "to some extent" limited to vehicles occupying the upper end of the market, and he gave no precise indication of the extent of its use for Jaguar's forthcoming XE midsize (in European terms) premium model. However, it will incorporate JLR's flexible, D7A modular aluminum architecture, with some use of aluminum for the body. Like other OEMs, JLR is looking at flexible material mixes.

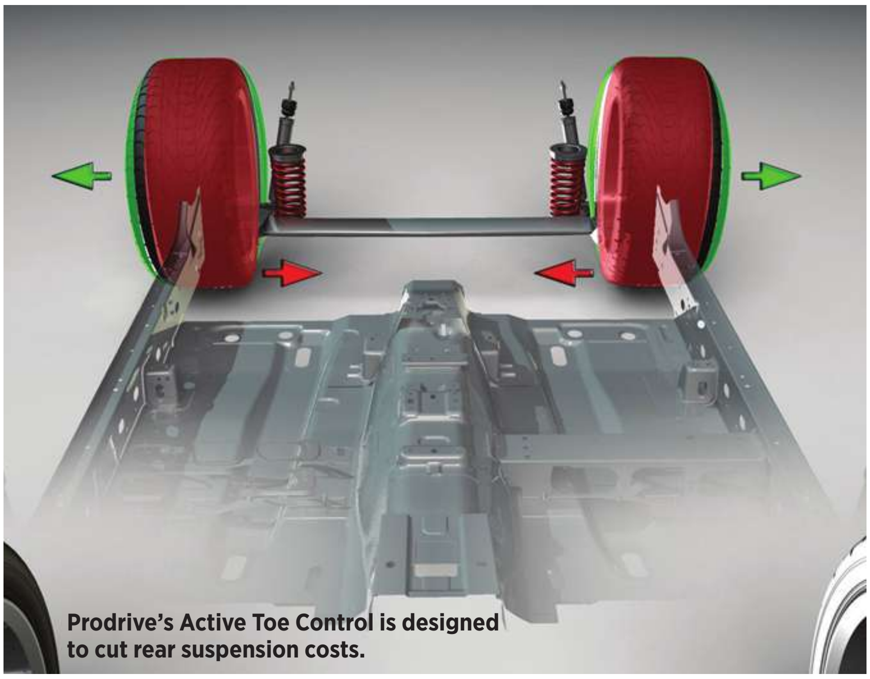
Choosing his words carefully, Ziebart said that with regard to more price-sensitive (high-volume) models, there may be a "soft transition" phase for the material's use for the "foreseeable future," particularly with regard to closures.

"The hard transition is when the decision is made to make the whole structure from aluminum," he said. This brings challenges, especially concerning joining technology, which, like aluminum, does not come cheap: "But we think our riveting and bonding technology is suitable for higher volume, too. In general for bodies, there is more diversity of materials being considered. You can bond and rivet almost any material in terms of material mix within certain boundaries. It makes us much more flexible in terms of which material to use."

However, he is very cautious about carbon fiber: "We have achieved so much from aluminum that in our opinion the added gain from carbon does not justify it."

Enhancing dynamics is a subject that is also at the heart of the design and technology ethic of **Lotus**, a brand that has always created cars of character via remarkable dynamics. Matthew Becker, Chief Engineer, Test and Development, cites attachment (or hard-point stiffness) as a key item in its design portfolio.

Driving good dynamics



Prodrive's Active Toe Control is designed to cut rear suspension costs.

Dave Rollett at Prodrive believes most car buyers do not know what good dynamics feel like.

"To achieve our extremely high levels of vehicle dynamics performance, we require very stiff suspension bushes, although it is critical to keep a good ratio between radial stiffness (high) and torsional/axis stiffness (low)," Becker explained. "High hard point stiffness helps at two levels: firstly, to keep a sufficient level of isolation (function of the rubber stiffness and attachment point stiffness), and secondly, to keep the noise and vibration transfer function levels low: It means that for the same excitation force, we will get lower levels of noise and vibration inside the car."

ANC aids dynamics

Lotus is also developing Active Noise Control (ANC), Becker said. It helps allow a setup for which the compromise is more oriented toward vehicle dynamics: "This generates higher input forces, but the active system cancels out some of the issues (up to a given frequency range), thus maintaining acceptable levels of refinement."

Together with advances in CAE and vehicle simulation, Becker believes ANC is one of the most significant developments in body and chassis engineering in the past five years.

Prodrive's Rollett agrees: "A customer looking for sports car dynamics may find an uncomfortably stiff setup pleasantly sporting, not knowing that such an extreme ride/handling compromise is not necessary."

Engineers really cannot let vehicle purchasers have exactly what they think they want, Rollett insists.

"Matching a vehicle's steering characteristics to buyers' expectations means satisfying both subjective demands for good 'feel' and objective requirements such as linearity of response that could affect safety," he said. "Many drivers, particularly in North America and China, may prefer low steering effort and interpret steering feedback as a lack of refinement. For safety reasons, good steering feel matters. Achieving this while delighting the driver means very careful management of the frequencies fed back through the steering wheel."

This is the point where objective and subjective meld.

Strength of character

At JLR—particularly at Jaguar—delighting the driver is also a must, and a team that includes Chief Vehicle Engineer Mike Cross does exactly that, Ziebart shared.

"With a mathematical tool like a simulator you can only develop chassis systems, such as spring and damper settings, so far; eventual settings are always finalized in a subjective way," Ziebart said. "Mike is an extremely valuable person in our company as he has the feeling for how our models need to respond, and it is not just about things that can be measured but even how the driver is positioned on a seat—he likes to sit as low as possible—that is so important."

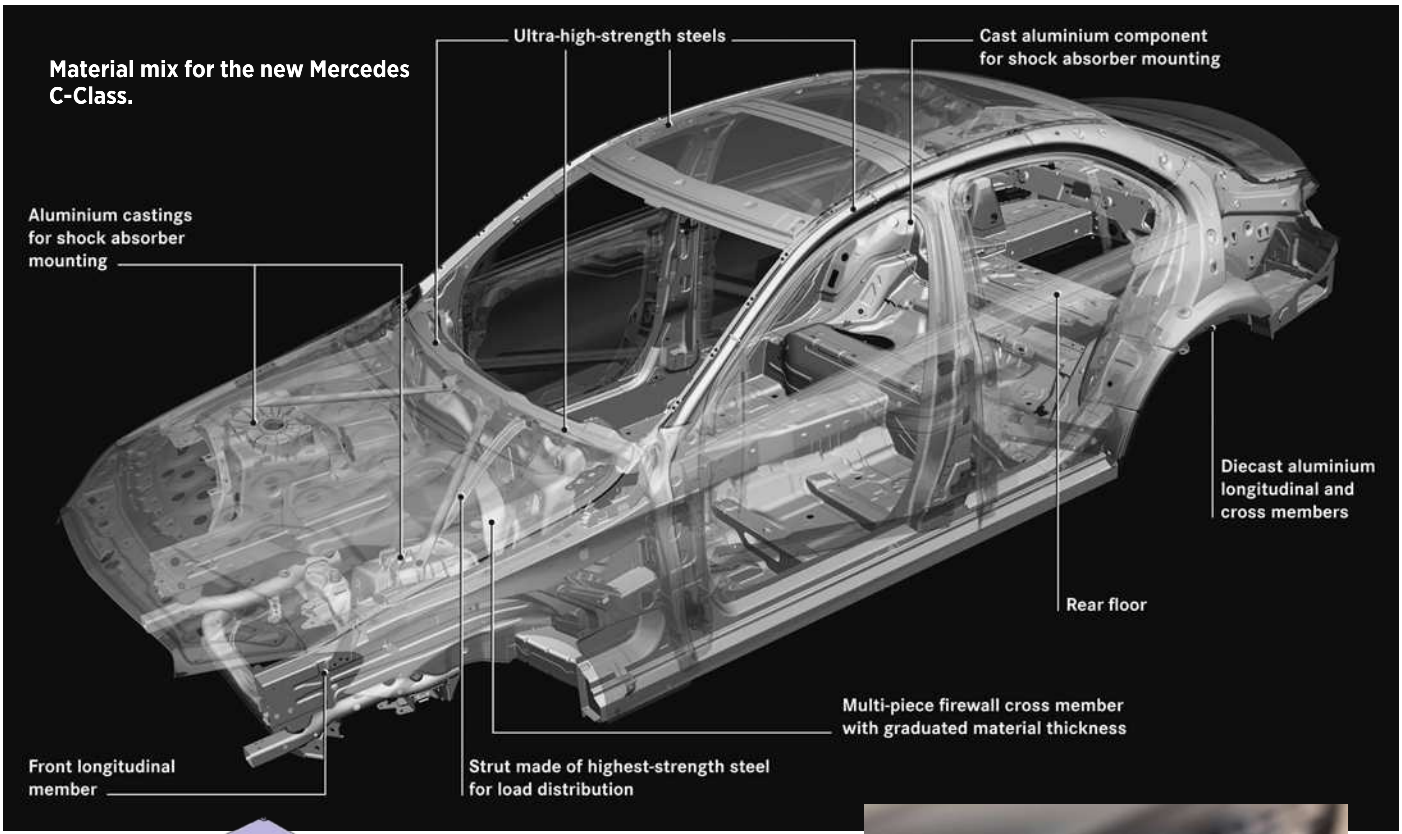
The JLR chassis team's fundamental vehicle character forming—the "feel" of the car—is complemented by sophisticated body control that does not detract from driver delight, according to Ziebart.

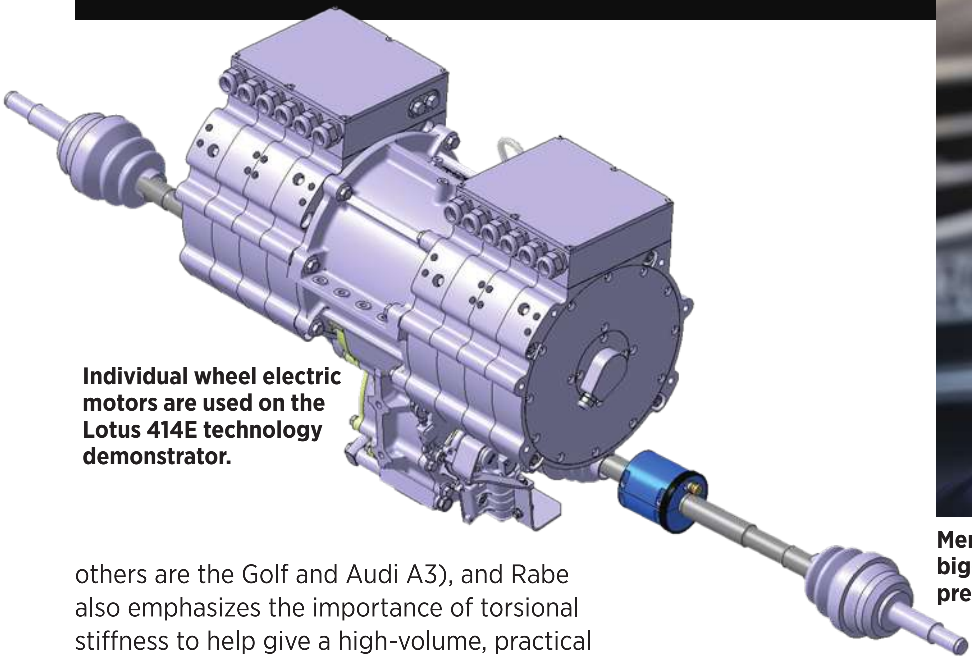
"Many of the systems are switchable and are accepted by both experienced and less experienced driver. But the opportunity for specific preferences is there," he said.

Increasing torsional body stiffness is a target for all OEMs; at JLR, the new F-type coupe is the ace at 33,000 N·m/° (24,340 lb·ft/°).

"I think we have reached such a level that further improvements will hardly be recognizable by even the most experienced driver," Ziebart said.

The SEAT Leon was one of the first VW Group cars to be built on the MQB chassis (the





Individual wheel electric motors are used on the Lotus 414E technology demonstrator.

Mercedes' Dr. Michael Krämer says that the biggest architecture design challenge was predicting the future.

others are the Golf and Audi A3), and Rabe also emphasizes the importance of torsional stiffness to help give a high-volume, practical hatchback model the character and sportiness that the brand is projecting.

"Early identification of load paths via simulation in the concept phase led, among other things, to the definition of the torsion ring concept at the rear of the vehicle, improving torsional stiffness—both static and dynamic—while allowing a really good relationship between weight (the car is 90 kg lighter than the previous Leon) and stiffness," Rabe said. "The driving dynamic is strongly influenced by the design of the body structure; in this area, energy input points are identified in order to improve local stiffness and therefore handling of the car."

Hot-formed ultra-high-strength steels with a yield strength of more than 1000 MPa (145 ksi) are crucial in some areas of the Leon's body (including A- and B-pillars and central tunnel) to save weight and also provide a good EuroNCAP safety rating for the car.

More power, more dynamic efficiency

Rabe aims to see future SEATs continuing to meet the essential criteria of greater efficiency in terms of fuel consumption and emissions: "But they still have to get more powerful and dynamic, and this can be achieved mainly through further lightweight construction."

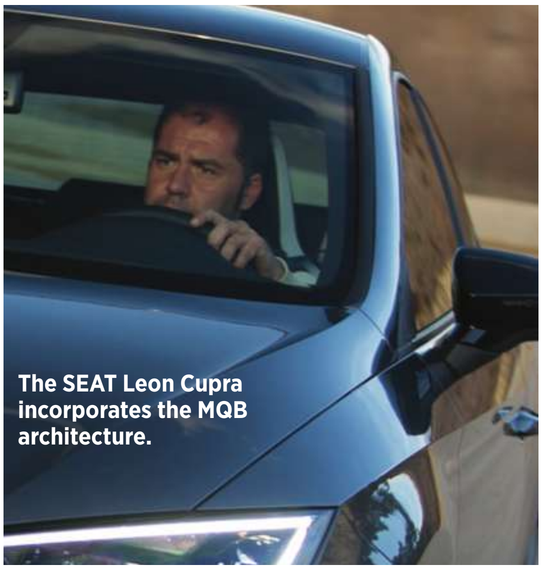
"Powerful" and "dynamic" are apposite adjectives applied to the new high-performance Leon Cupra, which uses torque vectoring to help get its 206 kW (276 hp) controllably and safely onto the road (or track) surface.

Driving good dynamics

At Lotus, Matthew Becker extols the benefits of Active Noise Control to complement dynamics requirements.

The VW Group MQB architecture is used by SEAT.

SEAT R&D Vice President Dr. Matthias Rabe says the MQB architecture allows the Spanish company to develop its own DNA.



The SEAT Leon Cupra incorporates the MQB architecture.

It is a technology that Prodrive's Rollett sees as becoming an increasingly major asset for chassis capability.

"It helps us align the feel of the car with the expectations that the customer has of a brand," he explained. "Because we can do so much in software, it allows lower-cost regional calibrations or brand-specific calibrations, on shared platforms. The same is true of Prodrive's ATC (Active Toe Control) developed to allow a low-cost rear suspension to deliver the benefits of sophisticated multilink arrangements."

By controlling rear-wheel alignment electrically, ATC permits different models derived from the same platform to be set up with individual handling characteristics simply by changing the control calibrations, allowing optimization for different markets without hardware changes.

Individual wheel motors

The advent of electric (and hybrid) vehicles that typically exhibit increased mass and inertia, which reduce agility and transient stability, open several possible avenues of body and chassis development to improve dynamics, including the use of individual wheel motors, which offer the opportunity to actively control torque distribution across an axle, producing a yaw moment that can in effect steer the vehicle independent of driver input.

Lotus has developed such a system for its 414E technology demonstrator, according to the company's Steve Williams, Manager, Vehicle Dynamics CAE.

"With individual wheel drive motors, the torque vectoring authority is much higher than with an active differential or single wheel brake intervention," Williams said.

The 414E provides up to 920 N·m (679 lb·ft) of drive or braking torque to each rear wheel independently: "This brings the benefits of increased agility combined with increased stability through damping of the oscillatory yaw behavior that would result from improving agility through passive means," he explained.

It is a whole new ball game for a customer's perception of dynamics. ■

Systems-engineering a new 4x4 benchmark

Chrysler Powertrain teamed with AAM to create the industry's most capable, sophisticated—and arguably most fuel-efficient—AWD/4WD driveline. Top engineers talk about their collaboration.

by Lindsay Brooke

The 2014 Jeep Cherokee's 4x4 driveline is being benchmarked by competitors due to its blend of capability and operational efficiency. (Lindsay Brooke)

"We set a high target for this program: Create the industry's most fuel-efficient four-wheel-drive system, with the greatest off-road capability and functionality," said Mike Kirk, **Chrysler**'s Director of Powertrain, Axle, Driveline & Manual Transmission Engineering, about the 2014 **Jeep** Cherokee. "And we knew from the start that our success was dependent on systems engineering—both internally and in close collaboration with our suppliers."

Transforming a front-wheel-drive crossover (the KL Cherokee is based on **Fiat-Chrysler**'s modular Compact U.S. Wide car platform) into a benchmark off-roader is no small feat, even without the requirement for a major leap in fuel efficiency—the base Cherokee is **EPA**-rated at 31-mpg highway. While **ZF**'s all-new 9-speed transmission, known as the 948 within Chrysler, would provide gearing benefits, Kirk's team realized the vehicle driveline also was key to significant efficiency gains.

"Our aim was to take at least 80% of the losses out of the [4WD] system when the customer doesn't need it," he noted. "So the idea of a disconnecting driveline emerged quickly in our early planning." Chrysler Powertrain had been working with **USCAR** as well as **SAE International**'s Driveline Committee as it investigated solutions for improving AWD/4WD system efficiency, without sacrificing the "Trail Rated" capability that's vital to the Jeep brand.

Cherokee is the first vehicle in its segment to feature rear-axle disconnect. The technology helps reduce fuel consumption by automatically switching from 4WD to 2WD, thus eliminating the parasitics of the second drive axle when not required by operating conditions. A similar feature is offered in the Chrysler 300 and **Dodge** Charger.

The driveline project actually started as a "decoupled" development off the critical path of the vehicle program, which began about a year later. "And I can tell you that's not enough time for something like this!" Kirk asserted. "This was a difficult one because we started it, then we jumped into the serial development of the new vehicle platform. Everything was done on an accelerated timeline."

Collaborative design

Chrysler Powertrain engineers Joe Kubina, Pete Jarzyna, Mike Nemeth, and Don Schmanski had been laying the technology foundation for the new driveline with their invention of a 4WD system for transverse-engine/front-drive architectures, which led to a U.S. patent issued earlier this year (and the 2014 Walter P. Chrysler Technology Award for the engineer quartet). The patent covers the power-takeoff unit (PTU) and associated components—a reduction hub controlled by a range selector with high, low, and neutral settings that is used to engage a planetary gear assembly that drives a transaxle's output shaft.

According to Kirk, a prototype 2-speed (hi-lo) PTU using the planetary gearset resulted, and Chrysler's Powertrain Synthesis Group evaluated it in a proof-of-concept vehicle. The results were encouraging and showed a useful efficiency gain. Further vehicle-level analysis included a thorough benchmarking of AWD and 4WD systems in competitive vehicles.

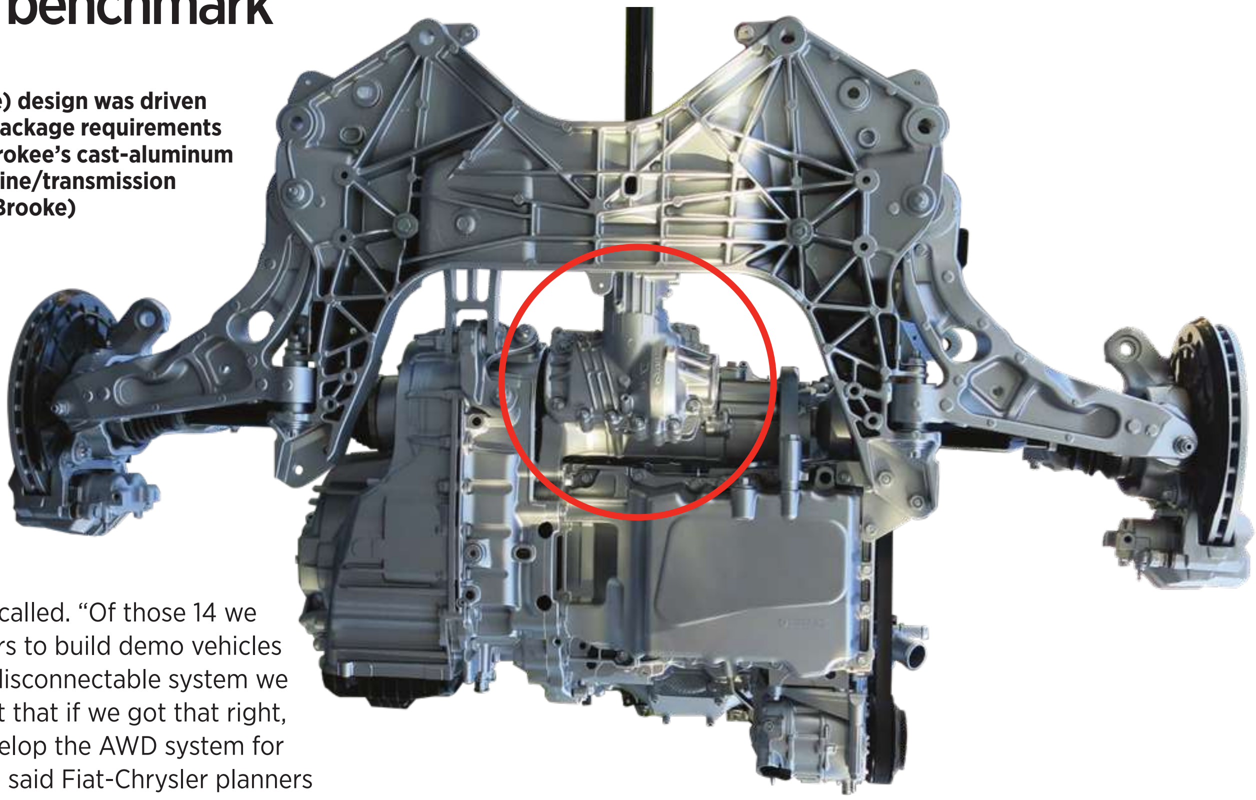
"We then did a paper analysis of a total of 14 different supplier-partners from around the world. We looked at everybody with systems expertise who could work closely with us in its development, and also manufacture the system to our high

Cherokee's 'naked' driveline shows no traditional transfer case. The axle-disconnect function delivers 2WD efficiency and 4WD performance.

Mike Kirk of Chrysler Powertrain's driveline engineering group praised his AAM colleagues in co-executing a robust, reliable, and sophisticated 4x4 system.

AAM's Phil Guys. (Lindsay Brooke)

Systems-engineering a new 4x4 benchmark



The PTU's (red circle) design was driven by extremely tight package requirements within the Jeep Cherokee's cast-aluminum front cradle and engine/transmission assembly. (Lindsay Brooke)

standards," Kirk recalled. "Of those 14 we picked two partners to build demo vehicles with the 2-speed disconnectable system we envisioned. We felt that if we got that right, we could then develop the AWD system for other vehicles." He said Fiat-Chrysler planners were already looking at a broad variety of C/D-segment vehicle applications.

The two finalist suppliers were each given a vehicle, and Kirk's team set a 90-day deadline for completing all analysis and design reviews. When the clock stopped ticking, Chrysler selected **American Axle & Manufacturing** (AAM) from the pair as its driveline-systems partner for the KL program.

"We've been working with AAM since the early 1990s; they supply the drivelines for our HD trucks," Kirk said. "We already had an outstanding relationship with them. While they were not in the AWD business with us, they fit well for the Cherokee project because of their expertise in core components and subsystems." And AAM already had development work under way, having anticipated the industry's need for driveline-disconnect capability with its EcoTrac system (see sidebar).

Kirk defines a true partnership with systems-proficient suppliers as one in which "we support each other's strengths, cover each other's

AAM's EcoTrac is an efficient package

In an interview with *Automotive Engineering*, Phil Guys, American Axle & Manufacturing Vice President of Product Engineering & Development, talks about his company's driveline technologies used in the 2014 Jeep Cherokee and destined for future applications, including the 2015 Renegade (BU). Industry veteran Guys (pronounced geeze) held senior engineering-executive positions at **Linamar**, **Ford**, **McLaren**, and **General Motors** prior to joining AAM. Here are excerpts from our interview.

How was the Jeep driveline program organized at AAM?
We built a team under Engineering Director Chris Phelps. He was the leader of the mechanical side, and also had the electronic controls team, which includes the software and mechatronics pieces, reporting to him. On the Chrysler side, Joe Kubina, their driveline Chief Engineer, was the lead. Chris and Joe were the 'matched pair' in pulling this technology off. Joe was outstanding to work with. He understood there would be issues and that we would work through them together. It wasn't a traditional suppler-customer relationship, with directives and 'execute backs.' It was truly problem-solving together.

Ensuring seamless operation for such a sophisticated system must've been challenging.
The way we've tuned it, we use our rear clutch to spin up the driveshaft to match the front, and when they're within 100 rpm of each other, a dog clutch locks the system together. Our clutch system has sufficient response and fidelity to be able to match to the shaft speed; we typically do it within about 500 ms throughout almost the entire operating speed range. At lower speeds we can ramp it up quicker. A sensor on the transmission handles speed correlation. It required a lot of development and learning to tune the system's responsiveness under varying temperature conditions, and deliver the level of refinement that ultimately is there.

AAM did a nifty job in component packaging.
Our design team had to get creative on both the PTU and the 2-speed rear with planetary gearset. There are a lot of tight tolerances inside and a lot of 'nested' parts. We actually moved the front differential into the PTU, and the small housing required quite a bit of temperature modeling for fluids and internal surfaces. We shared data with our lubricant partner **Lubrizol** regarding duty cycles and operating environments. Externally the PTU is a 'glove fit.' We had to customize the actuator because of clearance restrictions, and we recessed fasteners and sculpted surfaces just so. And while the components added about 10 kg, the system's efficiency is a net-net benefit.

What sort of system-efficiency gains are still possible?
We were targeting 100% drag losses. At highway speeds with our system fully disconnected, we deliver an 80% drag-friction reduction. And there's opportunity to reduce drag during low-speed operation. We're working to fully evacuate the fluid from the clutch circuit so that there's really nothing that those friction plates are going to spin through. Of course we have to 'feed' it quickly when the demand is there, but that's just the little bit left that we're working on.

Lindsay Brooke

Cherokee rear module contains planetary gearset for 2-speed (hi/lo) 4x4 functionality. (Lindsay Brooke)

weaknesses, and solve problems together." For the 2014 Cherokee, the solutions arrived at by Chrysler and AAM are best highlighted by reviewing the vehicle and its three available 4x4 systems. The base system, which Jeep calls Active Drive 1, is full-time 4WD without low range. It uses an electronically-controlled wet clutch housed in the rear drive module that can vary the amount of input torque according to driving conditions.

Active Drive 2 incorporates a reduction gear in the PTU that provides a 2.92:1 low range, effectively giving the Cherokee a Wrangler-beating 56.1:1 crawl ratio.

Finally, there's Active Drive Lock, standard on the Trailhawk model. It features the gear-reduction PTU and a true mechanical-locking rear differential. Electronic-control flexibility is provided by a Select Terrain knob on the console, which offers the driver a variety of terrain-focused operating modes—Auto, Sport, Sand/Mud, Rock, and Snow mode—along with hill-descent and ascent control, all of which required extensive software and algorithm development by the Chrysler and AAM teams.

All three systems employ the AAM driveline-disconnect technology it calls EcoTrac. There is no traditional transfer case. The rear axle (known as the rear differential module, RDM) is connected by driveshaft to the PTU packaged tightly on the rear of the transmission. Along with EcoTrac, AAM co-developed and supplies the PTU and the 2-speed rear unit.

"They [AAM] understood that the mode transitions had to be seamless to the end customer," Kirk said. "We have up to 111-times torque multiplication from the engine through the driveline. So the controls work was a key to making this fully functional and imperceptible for the driver." He noted that in Snow mode, for example, the Cherokee actually launches in 2nd gear in the 948 trans to give the customer better traction and a more secure 'feel' in slippery conditions. This required creation of unique shift schedules between 4-Hi and 4-Lo modes, and even the 'Rock' mode, to improve the performance and driveability under extreme conditions.

Disciplined software approach

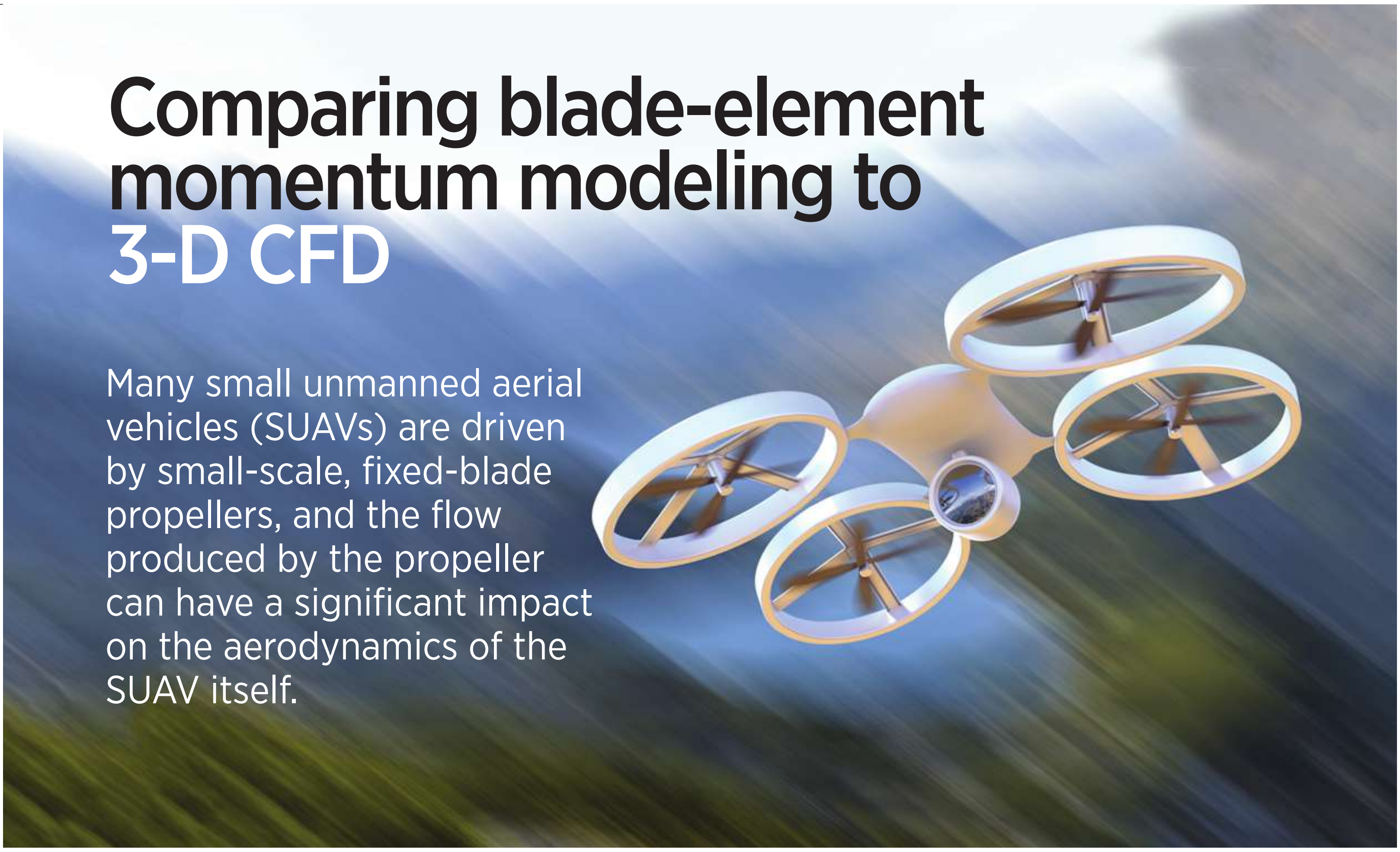
Software development began at the earliest stage of the program, Kirk said, and was segmented to a certain degree to ensure timing coordinated with the rest of the vehicle program. "For example, our Transmission System folks first focused on on-road functionality, because obviously we need that to test things like vehicle durability and cold/hot performance. From the perspective of controls and systems functional requirements, we weren't worried about 4-Lo performance in the early phase."

The ability to do hardware-in-the-loop and software-in-the-loop, and perform virtual analysis on the controls, helped keep the high-pressure program on track.

"AAM had a very disciplined but quick method of putting together proof-of-concept software to provide features and also fix issues," Kirk explained. "Then we'd come back with a cooperative approach to do validation before we introduced the driveline into the fleet of vehicles used for durability and reliability."

Contemplating his team's learnings on the KL driveline program, Kirk says the "wish list" for improving future processes is for even greater systems-level analysis and more standardized controls to help shorten the development cycle, particularly in critical areas such as NVH attenuation.

"As an industry, we can no longer rely on having to test everything to get to the best answer," he said. ■



Comparing blade-element momentum modeling to 3-D CFD

Many small unmanned aerial vehicles (SUAVs) are driven by small-scale, fixed-blade propellers, and the flow produced by the propeller can have a significant impact on the aerodynamics of the SUAV itself.

Small unmanned aerial vehicles (SUAVs) are becoming increasingly popular for surveillance and numerous other applications. These SUAVs come in various sizes, and the smallest are referred to as micro aerial vehicles (MAVs). For purposes here, SUAV will be used to refer to all UAVs that are portable by a man.

SUAVs commonly use small-scale, fixed-blade propellers for propulsion. Fixed-blade propellers means the blade is rigidly fixed to the hub so that the blade pitch cannot be changed for various flight conditions. Propellers mounted in a tractor configuration often have significant effects on SUAV aerodynamics. Therefore, to perform CFD simulations of a SUAV-propeller system, the SUAV and the propeller must often be simulated in a coupled fashion as the SUAV-propeller interaction is strong.

In the design and analysis of a SUAV, hundreds of SUAV-propeller coupled CFD simulations are needed. Performing high-fidelity, time-dependent 3-D Reynolds-averaged Navier-Stokes (RANS) CFD simulations in which the propeller is rotated relative to the aircraft is very expensive computationally. For compactness, this method will be referred to here as the high-fidelity blade model (HFBM). HFBM is an unsteady problem, therefore steady-state convergence acceleration techniques cannot be used.

In addition, the fine grid needed to resolve the detailed flow around the propeller blades makes the overall grid size extremely large. HFBM is the most accurate and high-resolution method of propeller modeling as all the 3-D, compressibility, rotational, transitional, and turbulence effects are modeled. However, the high computational cost of HFBM makes it infeasible when numerous simulations are needed—as is the case for many SUAV-propeller problems.

For computational efficiency, steady-state models approximate the time-average flow produced by a propeller. These models embed momentum source terms into the propeller region of a mesh to induce thrust and swirl into the flow field. Many of these momentum source models are based on blade-element momentum theory (BEMT). BEMT determines the thrust and swirl from 2-D airfoil data. However, flow around small-scale propellers can be very complex and highly 3-D in nature, making it difficult for BEMT to accurately predict the propeller performance in many instances.

For this study, researchers from **Mississippi State University** compared HFBM simulations to a BEMT model for two small-scale propellers to determine the validity of using BEMT to model small-scale propellers in a wide range of flight conditions.

High-fidelity blade modeling

HFBM simulations were conducted with an in-house code at MSU called CHEM. CHEM is a second-order accurate, cell-centered finite volume CFD code and has been validated and applied to a wide range of problems. All HFBM simulations were compressible, viscous, and assumed to be turbulent using Menter's shear stress transport (SST) turbulence model. While the Reynold's number was low (<150,000), the SST turbulence model was used to achieve settled solutions since unsteady vortex shedding occurs.

The HFBM simulations consisted of modeling an isolated propeller with no other bodies in the flow. The flow was uniform and at 0° angle of attack relative to the axis of rotation. Therefore, the flow at each blade was periodic and steady-state when viewed in the fixed-blade reference frame. Only one blade was modeled as the problem was periodic, and thus periodic boundary conditions were applied to the axisymmetric planes.

AFLR (advancing–front, local–reconnection) was used to generate the unstructured mesh. The entire mesh was rotated for unsteady simulations in which one time-step corresponded to one degree of rotation. A time-step study was conducted to ensure the time-step used was small enough to accurately resolve the flow field. The grid was rotated for five revolutions so the force on the blade was settled without any start-up effects.

Computational efficiency could be gained by simulating the propeller as a steady-state computation in the fixed-blade reference frame. However, unsteady computations were conducted for purposes of similarity to other CFD simulations in related research.

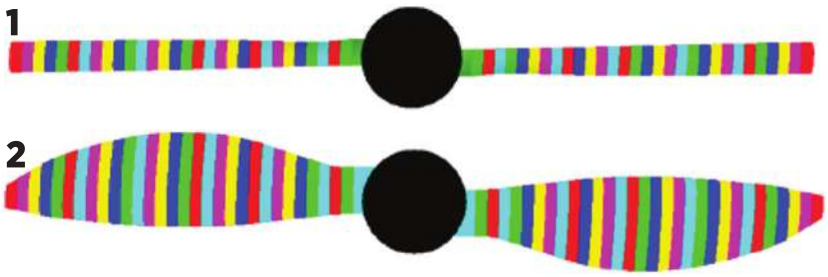
The surface of the blade was divided into sections so the CHEM code could output the total force (viscous and inviscid) vector on each blade element. No wall functions were used, and so the grid near the viscous surface was refined to ensure the boundary layer was captured in high resolution.

The top and bottom surfaces of the blade were each covered with 66 points. A far field size study was conducted to ensure the outer boundary of the computation domain was far enough away to not affect the propeller aerodynamics. The outer boundary was 12 blade lengths away from the propeller blade. The total grid size was 5.6 million elements, and the HFBM simulations were run in a few hours on the Talon super computer at the High Performance Computing Collaboratory of MSU.

Blade-element momentum theory

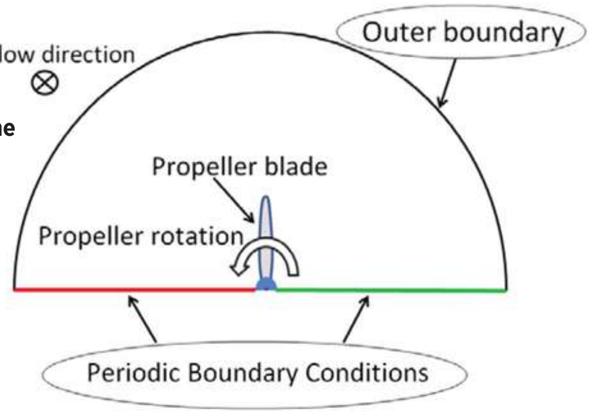
To implement BEMT, a set of lift and drag curves was needed for the NACA 4412. The lift and drag on a 2-D airfoil are functions of angle of attack, Reynolds number, and Mach number. The tip Mach numbers for the propeller cases were small, <0.32, so compressibility affects were assumed to be negligible.

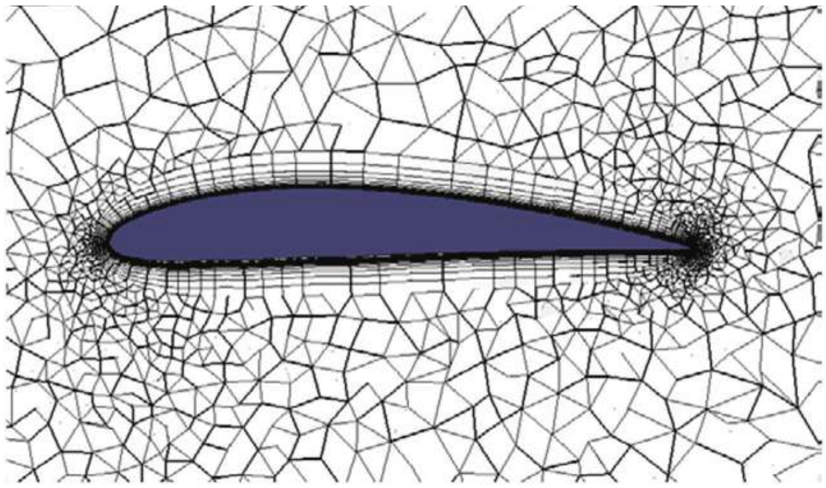
These low Mach numbers are typical for small-scale propellers due to the low flight speed and small propeller diameter. Some SUAVs have very high propeller rotation speeds, causing the flow at the blade tip to be compressible despite the small propeller diameter. In these cases, Mach number can be considered in BEMT. However, for the test



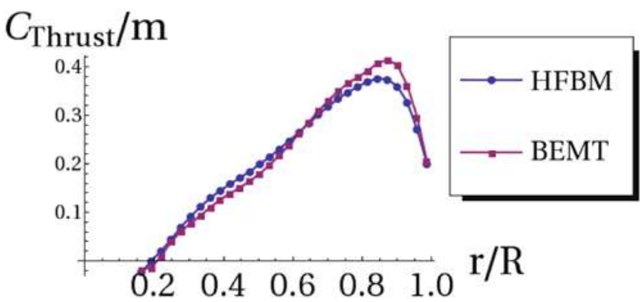
To analyze the significance of 3-D effects on small-scale propellers, two propellers were simulated using BEMT and HFBM. Both propellers were two-bladed, had a 10-in diameter, and were made using a NACA 4412 airfoil for the blade sections. Propeller 1 (top) had a high aspect ratio of ~11 and no chord variation or sweep along the blade. Propeller 2 (bottom) had an aspect ratio of ~5 based on the largest chord in the blade, and it had significant chord variation like many small-scale propellers.

Periodic domain for the HFBM simulations.





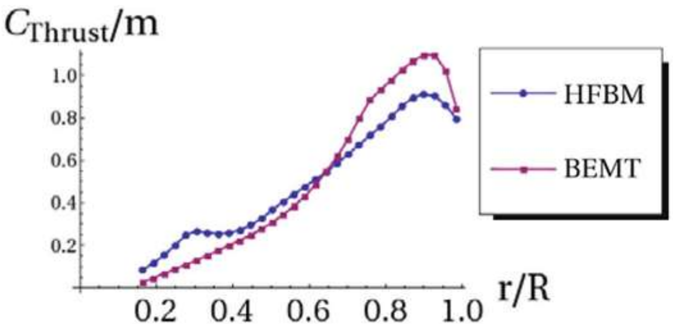
A cross section of the 3-D HFBM mesh around the blade at r/R = 0.4.



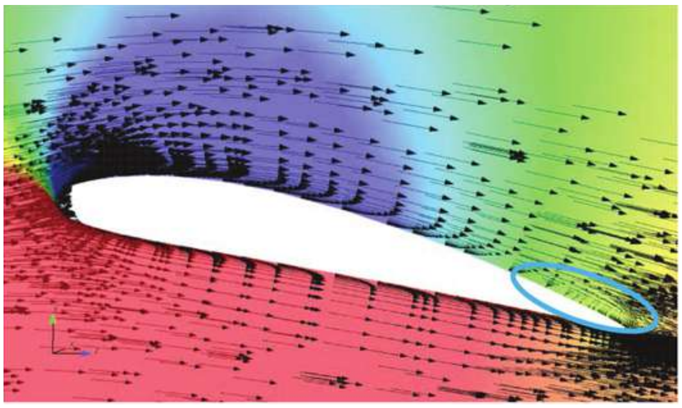
The spanwise thrust distribution (or thrust profile) for propeller 1 in cruise conditions. In this case, the BEMT model agrees very well with HFBM, with a 5.4% error. Most of the error is at r/R = 0.9 due to the tip loss effect.

cases here it was unnecessary to include compressibility effects, as the tip Mach number was low.

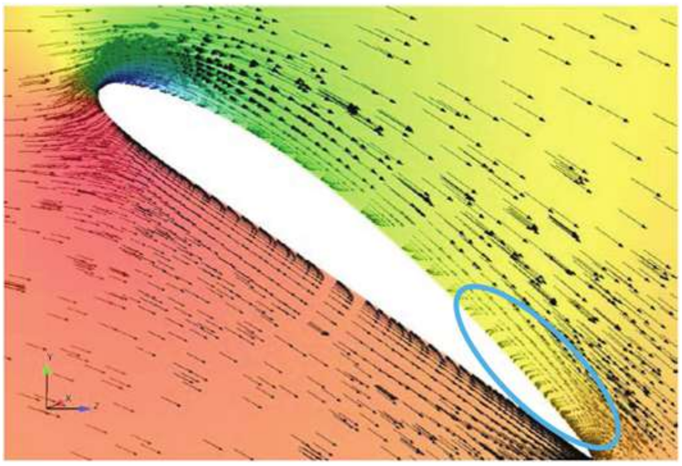
To conduct the CFD simulations to make the lift and drag curves, the Mach number was held constant at a moderate value of 0.15. Airfoil simulations covered the range of the Reynolds number experienced by each blade element (10,000-150,000). This range of Reynolds variation can have a significant effect on the airfoil's lift and drag, especially when a turbulence model is used.



The thrust profile for propeller 1 in low-speed conditions. BEMT in this case has considerable differences from HFBM with an error of 14.7%. More error is seen in the inboard and tip region of the blade due to separation.



The velocity vectors of the HFBM simulations at blade cross sections of r/R = 0.9 for propeller 1 at low speed are shown to visualize separation, which is pinpointed by an oval. The separation occurs toward the trailing edge on the upper surface of the airfoil.



Velocity vectors at cross section at r/R = 0.3 for propeller 1 low-speed conditions case showing separation. When separation occurs, the flow becomes highly 3-D in nature, with large spanwise components and BET loses accuracy.

A database of lift and drag data for the NACA 4412 airfoil was developed that covered the range of angle of attack and Reynolds number experienced by the blade elements for the propeller cases. For a direct comparison of BEMT to the HFBM simulations, similarity was maintained as much as possible between the 2-D airfoil CFD simulations and the HFBM simulations.

The CHEM code was also used to perform 2-D airfoil simulations with the SST turbulence model. For grid similarity, the same number and distribution of points used on a blade cross section for the HFBM grid was also used on the 2-D airfoil grid that was also made with AFLR. Therefore, the 2-D airfoil grid looked similar to the cross section of the 3-D grid generated for the HFBM mesh. In addition, the boundary layer was captured to a similar resolution as in the HFBM.

The BEMT model was programmed in Mathematica and only took a few minutes to run on a personal computer. Momentum theory was chosen, as it is one of the most commonly used methods to calculate the induced velocities for blade-element theory (BET). BEMT is well documented in literature and is easily implemented with an iterative solution procedure. Prandtl's tip and hub loss correction factors were incorporated with the model and no stall-delay model was used.

Analyzing results

For propellers with high aspect ratio blades operating in conditions with little separation, BEMT was able to closely predict the distribution of thrust along the blade, as the 3-D effects were small. However, as the 3-D effects increased by way of blade geometry or operating conditions, BEMT lost accuracy and thus applicability.

Correction models can be developed for and applied to specific tip geometries and propellers to achieve better agreement. However, these correction models for tip loss, hub loss, stall-delay, and rotational effects have difficulty in being generalized for a wide range of propeller geometries and operating conditions.

Despite these limitations in applicability, BET models are widely used when modeling propellers in CFD because they can be implemented as a computationally efficient steady-state model.

HFBM provided a time-accurate, high-resolution solution for the propeller that considered all 3-D effects. However, HFBM comes at a very high computational cost.

A fine-resolution grid is needed to resolve the flow around the propeller. In addition, the problem is time-dependent and restricted to a small time-step to resolve the fast propeller rotation. This high computational cost of HFBM limits its use for many applications despite the high accuracy.

It is worth nothing that the 3-D effects of separation and low aspect ratio that cause inaccuracies with BET are not specifically unique to small-scale propellers. Full-scale aircraft propellers, wind turbines, and other propeller or fan applications may also have strong 3-D effects, making BET insufficient. However, small-scale propellers on SUAVs are particularly prone to strong 3-D effects from blade geometry, non-variable pitch blades, and operation in a wide range of flight conditions.

The results presented here are intended to show situations in which the 2-D flow assumption of BET breaks down. Therefore, full 3-D CFD was compared directly to BEMT whose aerodynamic database was developed as similar as possible to the HFBM simulations. This comparison allowed a detailed analysis of the flow field to examine why BEMT loses accuracy in certain flight conditions.

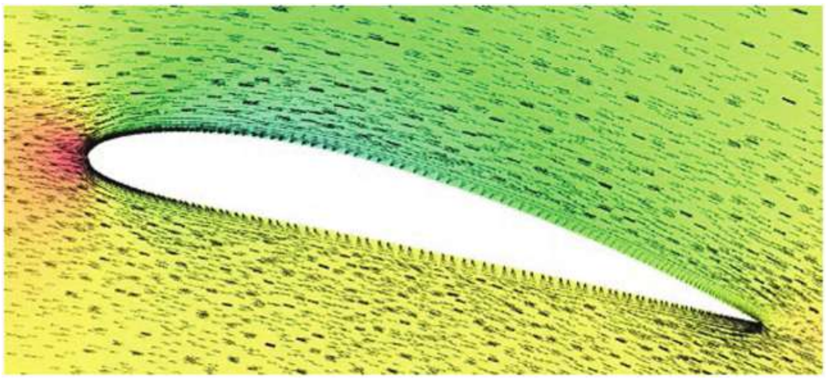
The physical accuracy of HFBM to experimental data is not guaranteed despite its consideration of 3-D effects. However, it is beyond the scope here to compare HFBM to experimental data, as HFBM is widely used and accepted in detailed propeller analysis. Other work has compared experimental results, rather than HFBM, to BEMT calculations. In such a case, global thrust quantities were compared, rather than thrust distributions along the blade, and similar results were found showing how BEMT is inaccurate in cases with separated flow.

Propeller-aircraft coupling

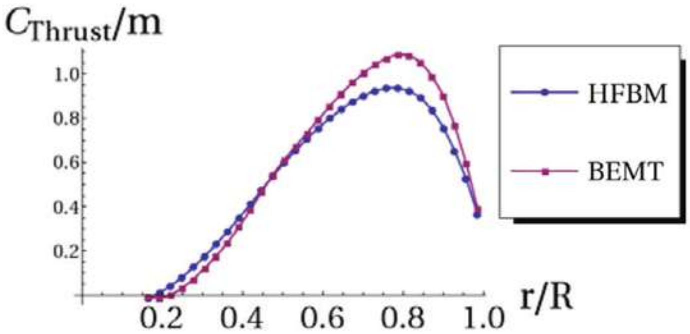
The main objective of propeller modeling in this SUAV context was propeller-aircraft coupled CFD simulation. Often, the desired information from these coupled CFD simulations are the time-averaged loads on the aircraft that require numerous simulations. To save computation time, a steady-state, computationally efficient momentum source method is desired.

Currently, BET is the most accurate and common method on which to base a momentum source model in CFD. When implemented in 3-D CFD, BET does not necessarily need another model to calculate the induced velocities, as the 3-D CFD solution calculates the induction by satisfying the Navier-Stokes equations over the flow domain. Momentum source term models based on BET that are implemented into 3-D CFD are well documented and are currently the most popular way to implement a time-averaged propeller model in 3 CFD.

For such models, the magnitude of the source terms are based on 2-D airfoil characteristics and are calculated from the inputs of



Velocity vectors at cross section at r/R = 0.3 for propeller 2 in low-speed conditions. Propeller 2 mainly differs from propeller 1 in that it has chord variation and sweep to the blade like many small-scale propellers. The velocity vectors in the first few cells off the wall point outward in the radial direction due to the centrifugal force from the rotation. However, the flow is not separated, as the velocity vectors do not point back towards the leading edge.



The thrust profile comparisons between BEMT and HFBM for propeller 2. BEMT has an 11.9% error in thrust for this case. This error is not attributed to separation, and must be attributed to the low aspect ratio, chord variation, and sweep of the propeller blade.

angle of attack, Reynolds number, and Mach number taken locally in the flow field. Therefore, the source terms are locally coupled to the flow field and adapt as the solution progresses. Due to the local inputs, different flight conditions and interference effects from aircraft couplings are considered in the calculation of the source terms.

Nonetheless, the 2-D flow assumption of BET fails to account for many of the complex 3-D flow characteristics that can significantly affect propeller performance, limiting its accuracy and range of applicability. Fundamentally, the BET assumes the flow over each element to be 2-D in nature.

However, the work here has shown that propeller aerodynamics can be highly 3-D and thus not accurately predicted by 2-D airfoil data. To obtain accurate loads on an aircraft that is affected by the propeller flow, the magnitude of momentum sources must be correct.

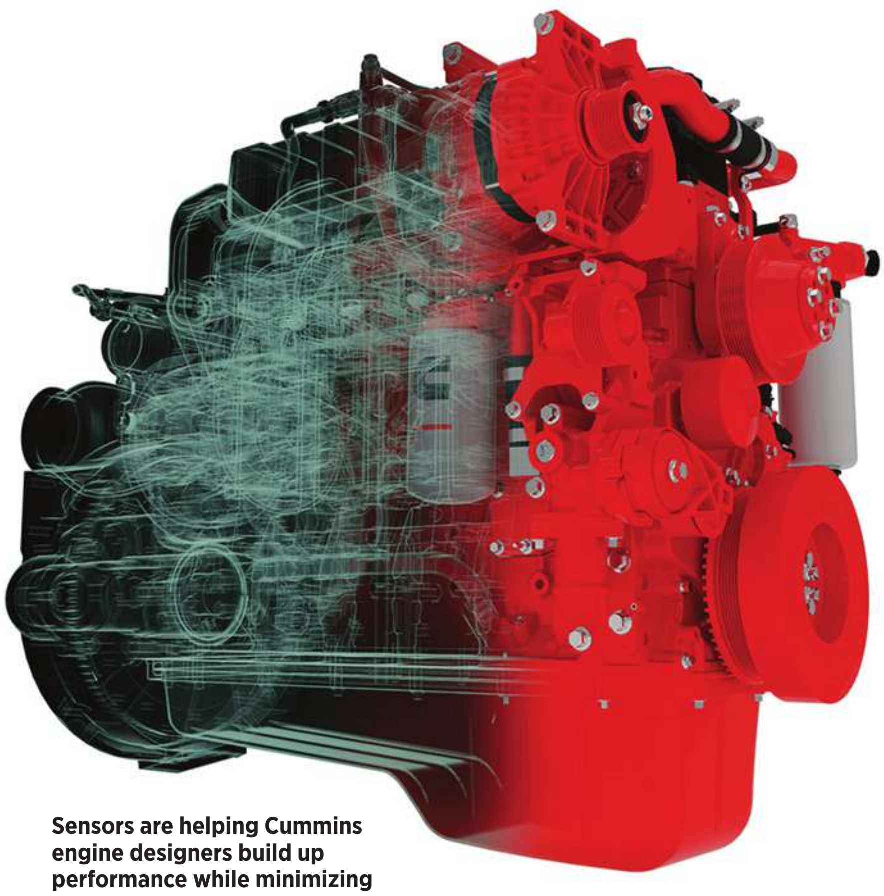
So while the momentum source term implementations of BET are locally adaptive to different flow conditions and aircraft couplings, the magnitude of the source terms can have considerable errors when 3-D effects are significant on the propeller, as is often the case for small-scale, fixed-blade propellers. ■

This article is based on SAE International technical paper 2013-01-2270 by Joseph Carroll and David Marcum, Mississippi State University.

Watching for ways to stand ABOVE THE CROWD

Sensors monitor a broad range of parameters to help powertrain design teams add features and improve performance.

by Terry Costlow



Sensors are helping Cummins engine designers build up performance while minimizing emissions.

Whether design teams are responding to the demand for more features and functions or meeting regulatory requirements, they're using sensors to link digital controls to the analog world. Sensor counts are growing, though engineers are also honing strategies that let them displace components by using virtual sensing.

The factors driving growth vary widely. The availability of inexpensive natural gas, U.S. **EPA** Tier requirements, and a need for more diagnostics are some of the major factors.

"The counts have been going up since the beginning of full-authority electronic diesel engines over 25 years ago," said Matthew Schneider, Chief Engineer and Chief Architect for Sensors at Cummins. "As the greenhouse gas regulations and the OBD requirements continue to develop, there will be a need for more inputs for different parameters of the engine or aftertreatment system. The addition of electronic aftertreatment systems has nearly doubled the sensor count."

Regulatory requirements have been a compelling force behind the transportation industry's adoption of electronic controls that help reduce fuel consumption and emissions. As engineers learn more about how the sensors and digital controls work together, they're always looking for ways to trim component costs.

"The sensor count curve trends upward over time largely as a result of new regulations," said Travis Anderson, Chief Engineer, Diesel Control Systems, at **IAV Automotive Engineering**. "But the curve does not necessarily increase monotonically. As we find better ways of doing things, occasionally that means some sensors can be eliminated. One example is the removal of DPFs. That eliminates the need for a differential pressure sensor, exhaust temperature sensor, and hydrocarbon dosing system sensors."

Though reducing component counts is always a goal, many developers feel that sensors often bring benefits that outweigh the costs. Electronic features are often solid differentiators in the marketplace.

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"Adding additional sensors and incorporating control and monitoring functionalities within existing machine controls adds little cost or complexity to the system, while providing significant benefits that machine end users are now demanding for greater efficiency and lowered maintenance costs," said Michael Olson, **Danfoss** Power Solutions Electronic Components Engineering Manager.

Adding features

Equipment makers continuously endeavor to give users more features and functions while also helping them reduce operating costs. As natural gas production has risen in the U.S., interest in this fuel alternative has risen. Letting an engine run on different types of fuels requires a lot of input from multiple sensors.

"Natural gas and diesel-natural gas dual-fuel engines must deal with a variety of issues not typically seen in diesel engines—knock being one of the more important," said Ryan Roecker, Manager, Powertrain Control for the **Southwest Research Institute**'s Engine, Emissions and Vehicle Research Division. "Dual-fuel engines in particular are often running with higher compression ratios than would be considered normal for a spark-ignited natural gas engine, leading to a greater propensity for knock."

He noted that new and retrofit natural gas and dual-fuel engines may require up to one knock sensor per cylinder. This could mean up to 16 knock sensors on some large engine applications, which would require more wiring, new control algorithms, and an increase in microprocessor performance.

Adding sensors can bring a lot of benefit for minimal cost, according to Michael Olson, Danfoss Power Solutions Electronic Components Engineering Manager.

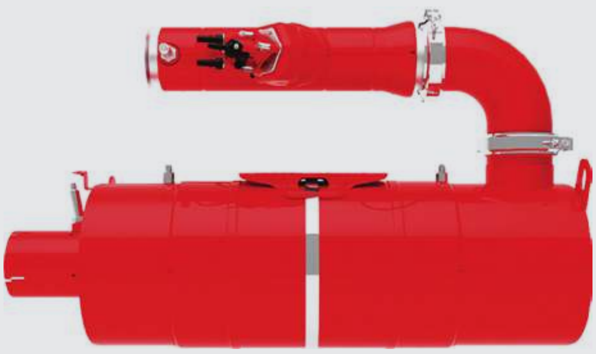
Many sensors are critical in efforts to improve operating efficiency. Sensors can help adjust blades to smooth roads and other surfaces. They can monitor speed too.

"We have used MEMS technology, inclinom-

Clearing the air

As tighter emissions regulations phase in, the electronic controls and sensors used in aftertreatment systems have become a major development area. A wide range of sensors must collect input from the various elements in the aftertreatment system while also communicating with engines.

"Over about the last decade we've moved from having few if any sensors in the exhaust, to having multiple temperature sensors, pressure sensors, lambda sensors, NOx sensors, and now even ammonia sensors and particulate matter sensors in certain markets," said Travis Anderson, Chief Engineer, Diesel Control Systems, at **IAV Automotive Engineering**. "Improving the durability of the emissions sensors is an important topic. It's not a surprise given the harsh environment in which the sensors operate."



Adding aftertreatment systems requires a solid control architecture that's built around input from multiple sensors. (Cummins)

As engineers seek more durable sensors, they're also looking for faster components. Speed becomes more important as more sensors are sending more data to more systems.

"Faster-reacting sensors enable improved machine control by eliminating the machine-induced errors that are typically associated with today's sensors," said Michael Olson, **Danfoss** Power Solutions Electronic Components Engineering Manager. "As non-road engines move toward the use of aftertreatment and/or EGR, more sensors are required."

The goal of reducing emissions while pruning fuel expenditures is prompting more cooperation between design teams. Increasingly, engineers from different projects work together to maximize vehicle efficiency instead of focusing only on improving a specific system. For example, aftertreatment sensors are highly integrated with engine controls.

"The objective is to optimize the performance of the overall system, and not just the engine or aftertreatment," Anderson said. "Efficient system operation requires the engine control system to be mindful of the status of the aftertreatment system. Sometimes we need to operate the engine in a less efficient manner to get the aftertreatment system up to temperature while still staying within emissions limits."

He added that once the aftertreatment system hits the desired temperature, the engine can switch to a more efficient operating mode. Sensors provide the information required to make those control decisions.

Design teams are using varied architectures to integrate sensors and control modules. Some dedicate a control module to aftertreatment, while others let the engine control module (ECM) manage aftertreatment.

"One would be to develop a separate control module for the aftertreatment system," said Matthew Schneider, Chief Engineer and Chief Architect for Sensors at **Cummins**. "Another approach would be to have the sensor outputs feed directly into the ECM and have the ECM determine the control. In many cases, the ECM with the engine parameter information, such as pressure and temperature, outputs this data to the sensor modules for compensation of each device."

Terry Costlow

Virtual sensors let Cummins measure parameters that aren't easily monitored.

Slope sensors from Danfoss help improve safety and efficiency.

eters, accelerometers, and gyroscopes to increase performance on slope sensors that are used for grade & slope control and other machine leveling applications," Olson said. "These same sensors can also be used as inertial measurement units to sense machine motion to control propel or other work function."

Sensors are helping make vehicles safer. Rollovers are a big concern in the uncertain environments confronted by off-highway equipment. Sensors can often perform double duty, helping operators improve efficiency while they watch for potential rollover situations.

"Speed sensors on wheels can detect slipping, so the system can determine when it needs to divert power from one wheel to the next," said James Sterling, Manager of Integrated Sensors at **Infineon**. "If one wheel's slipping and the controls know from the leveling sensor that you're on a hill, the system can add power to the opposing wheel and help the driver get out of a dangerous situation."

Virtually gone

Engineers often use specific sensors to measure different parameters like temperature or pressure. But they have also devised ways to measure some parameters without using a dedicated sensor. They can gather data by examining information provided by multiple sensors and determine the operating conditions for a sensor that isn't there.

"Virtual sensors will always be necessary to develop certain control functions," Schneider said. "Depending on the accuracy of the system requirements, virtual sensors can be utilized in many ways—from engine control, to air handling, to exhaust gas recirculation control. As prognostics become more prevalent and desired, there will be an increased need for virtual sensors—especially if this will allow for a prognostic without adding an actual sensor."

Eliminating sensors is often a way to reduce components and trim costs. But the concept can also be used to monitor parameters that aren't easy to measure using conventional components.

"Virtual sensors are not always about reducing component counts," Anderson said. "Perhaps more critical is the ability of virtual sensors to estimate system states that are difficult or even impossible to measure in the first place. One common example is the use of virtual NOx sensors to estimate engine-out NOx emissions after cold start when the physical NOx sensor is too cold to operate. Other common examples include virtual air mass flow sensors, EGR rate sensors, DPF soot load sensors, and SCR ammonia load sensors."

Virtual sensors can sometimes provide better performance than physical components. Although engineers can list many benefits for virtual sensors, they note that these benefits don't come for free.

"A virtual oxygen sensor can often be as accurate, and sometimes faster, than the physical sensor," said Roecker. "While virtual sensors can be designed to be quite accurate, the cost is almost always in terms of increased ECU processor load." ■

SAE INTERNATIONAL

IMPROVE INTERIOR PACKAGE DESIGN, INCREASE VEHICLE SAFETY, AND ENSURE INTERNATIONAL COMPLIANCE WITH THE SAE H-POINT MACHINE

A three-dimensional manikin that provides the physical representation of driver H-points, the ***H-Point Machine (HPM)*** is used to define and measure vehicle seating accommodations. Offering a deflected seat rather than a free seat contour as a reference for defining seat space, it is a vital tool in the design of interior packages.

Available through SAE International, the *HPM* is used in conjunction with SAE Standard J826 and is currently referenced in various federal and international regulations including NHTSA's FMVSS in the US and ISO standards. Utilized in testing for compliance to such regulations involving impact/crash, head restraint, or vision, it is the required safety certification tool for vehicle production in many countries around the world. Additionally, those who need to locate seating reference points and torso angles as reported by manufacturers employ the *SAE H-Point Machine*.

SAE provides comprehensive support for the *HPM* including, calibration, spare parts, and maintenance. And for advance design and research applications, the ***HPM-II*** is available, which includes reformed shells for a consistent and reliable fit in bucket seats, an articulating back for lumbar support measurement, and the ability to measure the H-point without using legs resulting in simpler installation.

View a free demonstration video at store.sae.org/ea/hpoint.htm to see how the HPM-I and the HPM-II offer a means of obtaining passenger compartment dimensions.

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Volkswagen's new Euro Passat switches to MQB matrix

The essential design criteria for the creation of a new generation of a high-volume production car has become thoroughly formulaic: improved fuel consumption; lower emissions; more performance; added safety; higher quality; extra features, particularly connectivity; increased carrying capacity; reduced weight; LED exterior lighting; diesel, gasoline and hybrid choices.

Volkswagen's new Passat, due for public reveal at the 2014 Paris Motor Show this fall, has been conceived to meet all of the above targets while demonstrating the further melding of computer and car technologies in a high-volume product.

At a special pre-launch media briefing at its Potsdam, Berlin, Design Center, VW Head of Design Klaus Bischoff added an extra dimension: "See this car in your rearview mirror and you will be in awe!" Maybe.

Its front end is certainly very prominent, with four chromed bars that bend inwards toward the distinctive headlamps in a trapezoidal shape. Over the grille and headlights is a further chrome accent that reaches across the whole front end. Headlights are halogen or LED, depending on model and specification. Daytime running lights on some models feature 32 LEDs with two separate modules forming respectively large and small U shapes.

With this eighth generation of a model that has sold 23 million units in those iterations, VW is emphasizing its focus on achieving a distinct identity, high perceived quality, and extensive digital capability.

Company executives are very confident of its quality; if it is indeed as good as it is designed to be, VW Group sibling company **Audi** will need to ensure that its own technology and quality remain in the ascendant.

Walter Maria de Silva, Head of Group Design, Volkswagen AG, underlined the strategic emphasis of the company's design ethic, saying that it is a 24-hours-a-day operation to meet the huge company's global commitments, which span a broad spectrum of time differences. He also emphasized that at the Potsdam facility, 24 nationalities were represented among its approximately 100 designers.

The Passat is the sixth of the Group's models to be based on the MQB modular transverse matrix platform (others are the VW Golf, **Seat** Leon, Audi TT and A3, and **Skoda** Octavia). It will be available in both sedan and station wagon forms, the latter arguably the more aesthetically pleasing. The current and very popular four-door coupe-esque Passat CC version of the car will continue for about 18 months, at which point a new equivalent is expected to be added to the range.

VW Development boss Heinz-Jakob Neusser emphasizes more communication with less complexity for the new Passat.

Both sedan and wagon were presented at Potsdam. In range-topping Highline form, styling was notable for its extensive use of brightwork, something that may be appreciated more in Asia than in other markets with a more restrained appreciation of what represents good taste.

Frontal treatment of the new VW Passat is a very significant element of its down-road graphics signature. Brightwork abounds.

The accent is on raised levels of quality in the new Passat. Note the ventilation grille spanning the dashboard.

As for the car's general signature, Bischoff emphasized (the sedan's) shorter overhangs—by 67 mm (2.6 in) in front and 13 mm (0.5 in) in the rear, longer wheelbase—and increased by 79 mm (3.1 in) to 2791 mm (109.9 in), with the cabin 33 mm (1.3 in) longer; A-pillar moved toward the rear of the car and lower hood compared to the outgoing model; and the rearward flowing line from the C-pillars. Larger-engine Passats get twin trapezoidal tailpipe treatment. The car is 12 mm (0.5 in) wider than the outgoing model, and the sedan is 2 mm (0.08 in) shorter than the previous model. The interior (in Highline form) has a strong luxury flavor. Although the new Passat is 14 mm (0.6 in) lower, it offers up to 26 mm (1.0 in) more headroom. Distinctive points include a dashboard incorporating a continuous horizontal band of air vents.

The driver benefits from a modular infotainment platform and gets an Active Info display with interactive virtual instruments and a combiner head-up display, with information projected onto a retractable glass surface inside of the windshield. Driving, navigation, and assistance information can be integrated into the graphic areas of the speedometer and tachometer. Both main instruments are more widely separated than would be typical to provide screen space for a map display. The configuration is similar to that offered in the new Audi TT. There is an App-based rear-seat entertainment system for tablet computers.

The infotainment system incorporates faster processors for optimized booting, faster sat-nav route calculation, smoother touchscreen capability, and improved voice-recognition system.

"It has a plethora of technologies for its class, but it provides more communication with less complexity," stressed Dr. Heinz-Jakob Neusser, VW brand Board Member for Development.

Safety aspects include Front Assist plus City Emergency Braking with Pedestrian Monitoring; Emergency Assist (the vehicle will stop in an emergency such as driver incapacitation); and Trailer Assist, designed to take the embarrassment out of reversing a trailer. A push button activates the trailer system. A rearview camera provides data for image processing algorithms to analyze trailer pivot angle. The car's standard mirror adjustment component is used by the driver to adjust the maneuver as necessary, without touching the steering wheel.

An essential part of every high-volume OEM's model range today is the incorporation of a hybrid. The Passat range uses a similar plug-in system to that offered in the Golf GTE. The system's combined power is 155 kW; the ICE is a turbocharged 1.4-L 115-kW (154-hp) gasoline TSI unit. All-electric range is 50 km (31 mi), with an overall range of some 1000 km (620 mi).

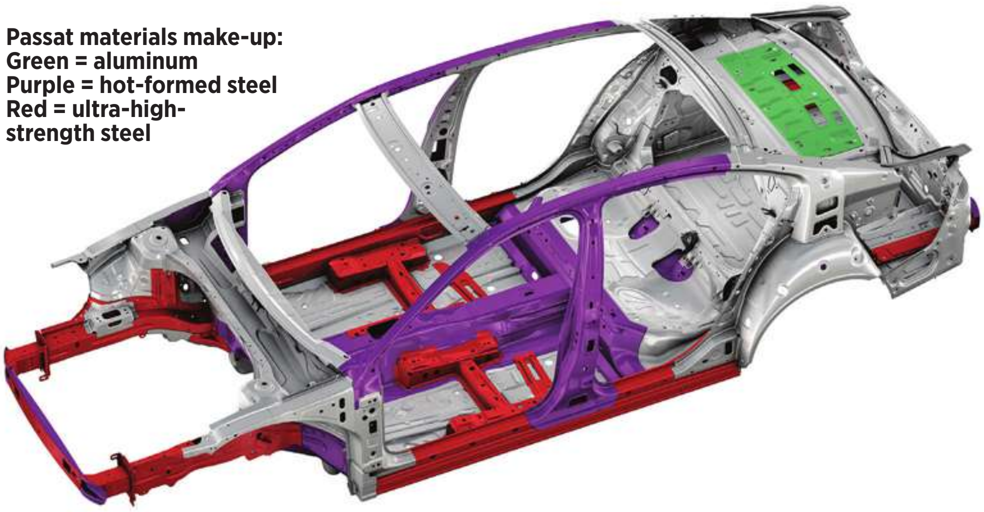
All engines used in the latest Passat are described by VW as being new to the model range. There are 10 TSI and TDI (diesel) units, all turbocharged and with a power range from 88 to 206 kW (118 to 276 hp). Fuel consumption and CO_2 emissions have been reduced by up to 20% measured against the previous-generation Passat's comparable engines. All Passats have stop-start and regenerative braking systems, and a double-clutch DSG transmission is available on all engine versions.

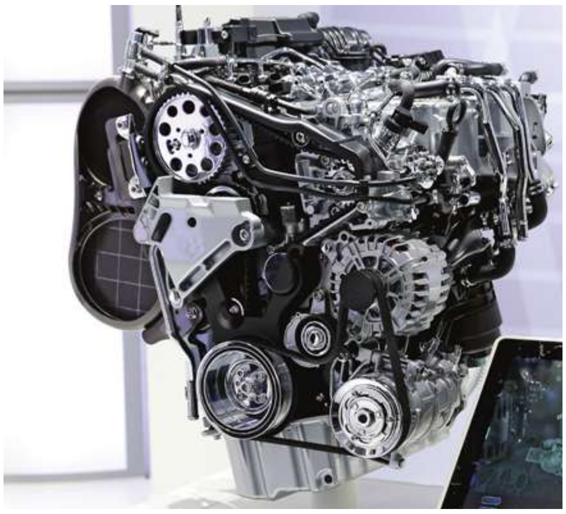
Active cylinder management is available for the 1.4-L 110-kW (148-hp) TSI, which has a combined fuel consumption of 4.9 L/100 km and 115 g/km CO_2 emissions.

VW is particularly pleased with its latest 176-kW (236-hp) TDI engine. This very powerful (for its capacity) 2.0-L bi-turbo diesel engine offers 500 N·m (369 lb·ft) from 1750 to 2500 rpm. Fitted

The new Passat station wagon. Across the range, weight savings are as much as 85 kg (187 lb) compared to the outgoing model.

Passat materials make-up:
Green = aluminum
Purple = hot-formed steel
Red = ultra-high-strength steel





The most powerful of the diesels for the new Passat produces 176 kW (236 hp) and 500 N·m (369 lb·ft).

to the Passat sedan, it provides a 240-km/h (149-mph) top speed, with the wagon 2 km/h (1.2 mph) slower. Both cars get 4MOTION all-wheel drive and a seven-speed DSG transmission as standard. Combined fuel consumption is 5.3 L/100 km with CO_2 emissions of 139 g/km. Zero to 100 km/h (62 mph) is achieved in 6.1 s.

The sum of all this is a new VW that edges a model upwards from its established B-segment firmly towards the C-segment and a premium label. In doing so it parallels similar movement by other manufacturers (e.g., **Mercedes-Benz** with the new C-Class nudging upwards toward not only E-Class but S-Class) and also introduces some very comprehensive infotainment and other electronic technologies. However, mass is reduced by up to 85 kg (187 lb).

Prof. Dr. Martin Winterkorn, Chairman of the Board of Management, Volkswagen AG (the Group), regards the Passat—as he does the latest Audi TT—as an indicator of where the auto industry is heading in terms of design and technology. He said at Potsdam that it demonstrates what engineers and specialists can achieve when pulling together, adding: "Cars and computers are amalgamating more and more."

Stuart Birch

Unmanned aircraft must rise above barriers for commercial applications

Historically, the unmanned aircraft system (UAS) market has been dominated by military applications from surveillance to active engagement. In the near term, the market's military focus is expected to continue. However, with projected growth from around $6 billion today to nearly $12 billion in 2023 (according to the **Teal Group**), large-scale commercial adaptation is not only possible, but likely.

On December 30, 2013, the **FAA** announced six U.S. test sites for the development of commercial drones and support systems. These sites will lay the groundwork for a new set of rules and operating parameters for UASs in and around commercial airspace.

This announcement and initiatives from companies such as **Amazon** have caused speculation about the different types of operations that could be enabled by drones—from food and flower delivery to high-speed police surveillance. However, a full array of technological and operational roadblocks currently prevent mass commercial adoption of UASs.

Aircraft technology: Autonomy vs. remote piloting

In today's intelligent machine world, the line between algorithms and the brain has become blurred. For years, the most sophisticated UASs have employed "autonomous" algorithms that allow them to operate for hours without human intervention or control. This autonomy can be perceived as true intelligence but also as dangerous—raising concerns about accidents and moral and legal accountability.

Although autonomy is alluring to commercial users thanks to lower personnel costs, it is unnecessary and overcomplicated for most near-term commercial applications and may inhibit regulatory approval and public acceptance.

Researchers from **Jabil Defense and Aerospace Services** and **UAS SafeFlight** believe that for the next 10 years, "human-in-the-loop" aircraft that use autonomous systems to alert the operator and allow the person to take

It is expected that consumer product delivery and high-speed police surveillance will be enabled by drones.

control will have the best chance of winning over regulators and the public alike.

Although less elegant than fully autonomous systems, this hybrid approach is significantly more palatable and pragmatic as an initial step. This is not to suggest that full autonomy is impossible. However, the researchers consider a UAS launching, delivering a drink or supporting a police officer, and then returning to base without human intervention to be a scenario beyond the 10-year time frame.

The UAS designs most likely to be certified for flight in urban areas will use this hybrid approach. Therefore, highly reliable communication between the drone and the human operator, using a system able to prioritize traffic, is a critical concern. However, current cellular bandwidth is not adequate and existing protocols for line of sight (LOS) systems are not scalable.

Modular scalability and standardization

In the airframe and propulsion areas, UAS developers can draw insight from the standardization of military and commercial aircraft. Currently, there are more than 120 different unmanned aerial vehicle (UAV) models with varying payloads, propulsion systems, and power sources. By comparison, there are less than a handful of new fighter jets and only a few standard commercial aircraft models, with only three engine manufacturers.

Standardization of UAS hardware is essential for cost-effective manufacturability that will help drive mass commercialization. The future will depend upon modular components that are fit for purpose, aligned with industry standards, and easy to scale up as demand increases. However, the UAS manufacturing landscape is currently fragmented and not standardized.

Today, the largest gap in fit-for-purpose is in UAS propulsion systems. Smaller drones are operating with adapted model airplane engines, either gas or battery powered. These engines were not designed to carry valuable goods and lack sufficient reliability for operating in commercial airspace. In the near term, the authors anticipate the emergence of a liquid fuel engine that is based on existing technology but designed specifically for UASs and able to pass engine reliability tests similar to those for commercial engines.

The myriad of missions expected to be performed by UASs will require modularity to drive down costs. A single UAS platform and engine must be able to complete several different types of missions to provide economic benefit to the end user.

For example, to justify investment in a UAS, a municipality needs to be able to configure the same vehicle for different uses, such as speed monitoring, first responder support, and crowd surveillance, using modular kits. In a commercial example, a business delivering goods may need to modify the hardware to accommodate different payloads such as fragile flowers, perishable food, or bulky books. These modules should be quickly and easily interchangeable.

To achieve modularity and cost-effective, scalable production, the industry must draw on models from the commercial aviation and consumer electronics sectors, which are based on global standards and produced using consolidated global manufacturing, rather than disparate assembly operations at the level of a hobby shop.

Communications efficacy

Historically, **U.S. DOD** drones have relied on line-of-sight (LOS) solutions or satellite communication (SATCOM) approaches. Although these point-to-point solutions have proven adequate so far, primarily because the number of UASs operating in any one geographical area continues to be quite limited, they will not meet the needs of commercial drone operations.

Currently, it would be difficult to find any 5 mi^2 area on earth in which even 10 UASs have operated at the same time. However, by 2018, 7500 small drones are expected to be in the air over the United States.

Networked mobile technology and connectivity are expanding exponentially. Using networked mobile infrastructure as the backbone of UAS piloting communication will be essential to support growth of commercial drones. To this end, networked mobile protocols and approaches must be adapted to meet the connectivity needs of a high concentration of UAVs in flight.

While the unmanned aircraft system (UAS) market has been dominated by military applications from surveillance to active engagement, large-scale commercial adaptation is not only possible, but likely.

Solutions at scale

To address the above issues, the authors propose efforts across three main areas.

• *Industry-standard propulsion hardware*
The combustion engine has been a reliable solution for nearly 100 years. Despite several billion dollars invested in batteries and hybrid power solutions, very few technologies have come close to the energy density or cost-efficiency of gasoline/diesel engines. Existing small liquid fuel engines (two-stroke technology) can provide a viable solution for commercial applications, providing on-station time surpassing that of batteries and high reliability in operation. The FAA should select two to three engine designs and require a Federal Aviation Regulations FAR 33 or similar test to prove their reliability. With two to three approved propulsion solutions to work with, UAS designers can focus on airframe variations.

• *Modular mission kits*
Scalability of UAS manufacturing requires basic architecture with interchangeable, mission-specific modules, such as cargo payloads, sensors, and transmitters, rather than separate, customized designs, akin to today's computers and smartphones.

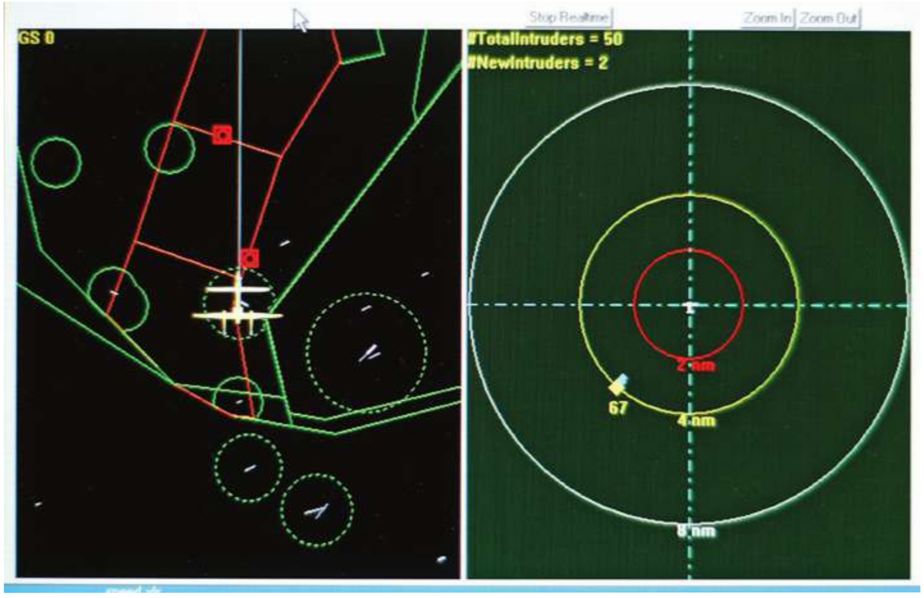
UAS manufacturers should focus on systems architecture as well as software and data algorithms, while leveraging existing electronics suppliers—which have the required expertise and infrastructure—to cost-effectively manufacture the modules and their electronics. It took 500 years for the shipping industry to adopt the modular container, but under 20 years for personal computers to become interchangeable. It is expected that UAS designs will become common and modular in even less time.

• *Communication over mobile technologies*

Commercial UAS command and control systems will need to leverage multiple personal communications service (PCS) connections through multiple streams. These communications are likely to utilize existing carriers and their installed cellular infrastructure and towers and will require from a few to more than 20 simultaneous cellular connections. Multiple connections will ensure both safety and redundancy across different UAS classes and missions. For example, a mission that requires continuous video feed at high speed will demand more connections, whereas a simple delivery may only need a few.

In a scenario where a UAS mission requires 12 simultaneous connections in an area served by three unique cellular carriers (e.g., **Verizon**, **ATT**, and **Sprint**), hardware and software must balance bandwidth for four connections each across the three providers. For efficacy and redundancy, the system must drive connections with each carrier across a unique tower. In most cases, an UAS with an altitude of 100 m will naturally distribute the four connections among available cellular towers, but must be coordinated through purpose-adapted software and hardware.

In addition, the hardware on the drone needed to establish multiple connections must be effectively managed and size, weight, and power (SWAP) must be considered. Modern manufacturing and the latest electronic advances will be required to effectively make the trade-off between minimizing SWAP and maximizing connections. Once custom hardware utilizing multiple compact cellular data solutions is tested and certified across platforms, up to 20 simultaneous connections for commercial drones will become a reality.



Sophisticated UASs have employed "autonomous" algorithms that allow them to operate for hours without human intervention or control. This autonomy can be perceived as true intelligence but also as dangerous—raising concerns about accidents and moral and legal accountability.

Under the assumption that a human operator must be able to take control of an UAS at any time, command and control technology is of paramount importance. UAS command and control is bi-directional: the UAS must send operational sensor data (position, avoidance system detections, etc.) and the human-in-the-loop must be able to send control data (e.g., turn left, maintain altitude) to the UAS. Latency in the network system must be minimal or it can adversely affect safety and operability.

However, the overall amount of data being sent, in either or both directions, is (compared to the capacity of the system) rather small. Even when the human-in-the-loop is operating the UAS, low data rate video, on the order of a few frames per second, is sufficient. With the exception of low data rate video, command and control data comprises a few thousand bits per second.

The most simplistic approach would be to send all command and control data over all available paths. While this is not bandwidth-efficient, the trade-off (in simplicity of implementation and practically guaranteed delivery of the data) makes it a good option. However, to be viable, current bandwidth software must be developed to account for duplicative receipt from multiple channels with very high efficacy and low latency. This type of software exists, but needs to be adapted for UAS purposes and subsequently tested and certified by the FAA.

Overall, the future use of UASs in myriad commercial operations is highly likely. How rapidly this becomes commonplace depends on the ability of UAS operators, designers, and regulators to reduce barriers and align on key technology goals. Existing communication, propulsion, and manufacturing technologies can and should be rapidly adopted for mass commercialization of UASs. However, adoption will require industry collaboration and agreement, potentially in conjunction with FAA test sites and certification.

This article was written for *Aerospace Engineering* by Scott Gebicke, President, Jabil Defense and Aerospace Services; and Tim Krout, Founder, UAS SafeFlight.

COMPANIES MENTIONED

AD INDEX

Laura Kurtz, Manager, Recruiting at Ford Motor Co.

Meeting the need for engineering talent

Perhaps no one knows the realities of the U.S. engineering job market more than Laura Kurtz, Manager, U.S. Recruiting at **Ford** Motor Co. The shortage of engineers and the increased competition among corporations for top engineering talent have made the filling of both entry-level and experienced positions at the "Blue Oval" a year-round effort. SAE Magazines recently spoke with Kurtz to gain insight into the hiring process at Ford and the types of skills that can help a candidate stand out from the pack.

How do you feel universities are preparing young engineers for the workplace?
At the schools Ford recruits at, we are confident that their engineering students have the skills that we're looking for. We look for students in traditional fields such as mechanical and electrical engineering, and we are specifically looking for students in the area of mechatronics, which is electrical and mechanical systems and how they work together. But Ford also looks for students who have business skills as well, such as project management and financial analysis.

What are your main resources for finding young talent?
We use traditional methods and leverage technology such as social media. Our Ford managers have established relationships with key universities, and we find that students really enjoy the face-to-face contact, not only with the engineering managers but also with students who have just been hired into Ford more on a peer-to-peer level. Students want to know what they'll be doing, and that entry-level engineer can really shed light on the experiences they've had since hiring into Ford. We are definitely also using social media. It's all about communicating to students why come to Ford, what are some of the benefits, and what it's like to work at Ford on a regular basis.

In terms of the engineering background of new hires, what is the mix like?
We certainly have a lot of need for mechanical engineers. With electrical, we use a lot of controls engineers in our manufacturing facilities for robotics, assembly, and conveyor systems in the plants. We also are looking for people who have dual degrees, computer science and electrical, because so many of our vehicles have the MyFord and MyLincoln Touch technology with SYNC. We need experts who can help us design those systems because that's what the consumer wants.

How have you seen the hiring needs of the industry change in your time as Recruiting Manager?
I've been in my role for four years, and it's been an exciting four years. As the auto industry has rebounded, our hiring needs have increased year over year. With that, the economy is picking up, so the talent market is getting very competitive, so you can't just rely on business-as-usual practices. We have to go out and we have to seek out passive candidates.

What are some ways you reach out to experienced engineers and what are the skills you're seeking?
We use a myriad of means to seek out experienced engineers, including traditional methods such as job postings. We use tools like Indeed and LinkedIn to find people with the interests that we're seeking. One of our best sources of talent is employee referrals. In terms of skills, we're really focusing on robotics and controls engineering. We look for experienced engineers with regard to vehicle electrification, hybrid technology, and electronics. We're also looking for foundational skills, experienced engineers who can manage a project and operate like mini-CEOs of their commodities.

How do you recommend that young people try to get some of that management experience?
The two things that really impress Ford recruiters are students that have a passion for the industry, so students who have been in programs in college such as Formula SAE or vehicle challenges because they're already engaged in our industry. We also look for students who have demonstrated leadership in their college curriculum. Those are skills that are very transferrable, and that really sets a student apart from other students.

Are there efforts to sway engineering students to consider Ford who may not initially be considering the automotive industry?
We like to tell the Ford story, and part of that story is the work that Ford is doing around technology and integrating technology in the vehicles. We really are a high-tech company with the equipment that we're putting into vehicles. That's why it's really important that we're competitive because we're competing for the same computer engineering talent as some of the big computer and Internet companies. We want students to know that they can work on the same big, sexy projects as Silicon Valley here in Dearborn.

Matthew Monaghan

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