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AUTOMOTIVE, AEROSPACE, OFF-HIGHWAY

A quarterly publication of SAE INTERNATIONAL and SAE INDIA

Volvo backhoe loaders

Production moves east

Next-generation GDI
Preparing for new rules

Process management and benchmarking
New Product Development for Cat dump trucks

Integrated automotive gateways
Enabling connected cars

Volume 2, Issue 1

March 2015

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Volvo Group is moving development and production of backhoe loaders and motor graders to SDLG, which has been present in India since 2009.

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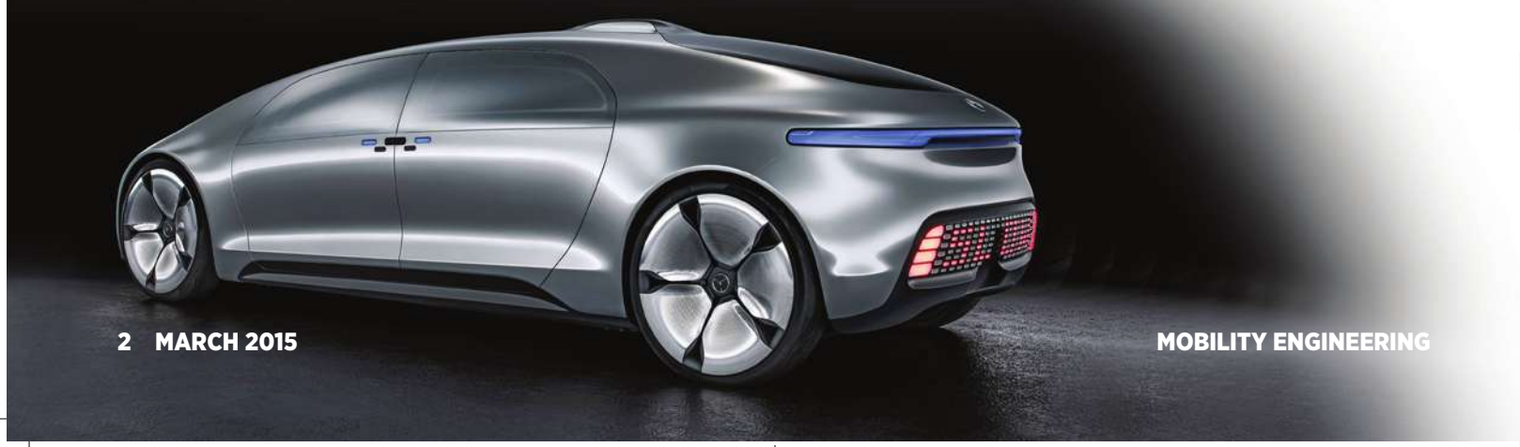

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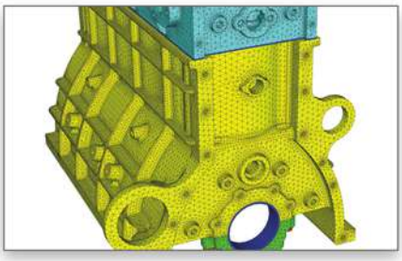

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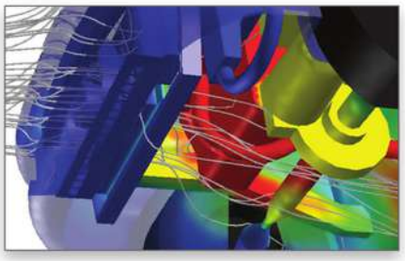

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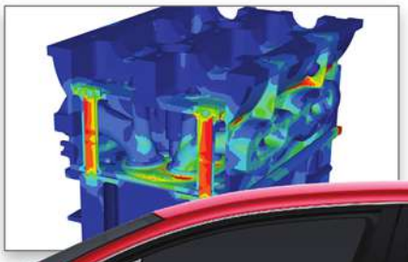

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EDITORIAL

Automotive 2025

As technical development accelerates, socio-economic forces buffet markets, and the industry becomes more global, predicting the automotive future is becoming more of a challenge. Now that we are well into 2015, some industry watchers have released their predictions looking out to 2025 in an effort to help the industry anticipate customer needs in the next decade. The decisions made by executives now will affect automotive engineering, especially in the later part of this decade.

Among some of the more interesting findings of a new **IBM** Automotive 2025 global study released in January is that the automotive industry will need to offer greater personalization for its products and services and that fully autonomous/automated driving will not be as commonplace as some think. The study by IBM's Institute for Business Value is a follow-up to an earlier report looking out through 2020. Company researchers interviewed 175 executives from automotive OEMs and suppliers, as well as other thought leaders, from 21 countries on customer expectations, growth strategies, mobility requirements, and ecosystem disruption.

Changes in consumer expectations were the most dramatic shift between the 2020 and 2025 studies. Consumers will be more engaged not only for improved driving and digital experiences but also for the opportunity to co-create cars along with related services such as infotainment. Nearly two-thirds of executives saw mobility services or car/ride sharing as an area for greater collaboration with consumers.

Less than 10% of executives thought that fully autonomous vehicles would be commonplace by 2025, and only about 20% believed that a fully automated environment—meaning the driving system handles all situations without monitoring and the driver is allowed to perform non-driving tasks—would be routine. However, almost 90% felt that partially automated driving, such as an expansion of today's self-parking or lane-change assist technologies, would be commonplace. A little over half said that highly automated driving—for which a system recognizes its limitations and calls a driver to take control when needed but allows the driver to perform some non-driving tasks in the meantime—would also be adapted by 2025.

Model year 2025 will also be significant for automakers selling in the U.S. that have to comply with the **EPA**'s 54.5-mpg fleet average fuel efficiency rules. The need for compliance has brought about a huge spike in propulsion patents in the powertrain area, according to a study by the Intellectual Property & Science business of **Thomson Reuters**. Analysis of data from 2009 through July 2014 shows that patent activity in propulsion technology grew from fewer than 2000 patents to nearly 12,000—more than any other automotive technology area.

Toyota was the auto world's top innovator from a patent perspective, with over 7000 patent assignments to the company during the period. It is one of five Japanese auto companies—the others being **Honda**, **Denso**, **Seiko Epson**, and **Mitsubishi**—in the top 10, the most of any country. **General Motors** was the only U.S. company in the top 10, in seventh with just under 3000 patents. Hyundai, the lone Korean automaker in the top 10, was the fastest-growing patentee, climbing from under 500 in 2010 to third on the most-assigned list.

Although automakers' powertrain patent numbers are growing, there will be a need for multi-OEM cooperation on the most research- and resource-intensive technologies. Electrification is one example, with recent high-profile fuel-cell technology tie-ups involving Toyota/**BMW**, GM/Honda, and **Ford**/**Daimler**/**Nissan**.

The IBM study confirmed that industry cooperation, especially with outside entities, will set the stage for long-term success and industry leadership. About three-quarters of the executives polled rated collaboration with other industries as the best opportunity for industry growth, and they expect nontraditional industry partnerships to have a key role in the automotive ecosystem by 2025.

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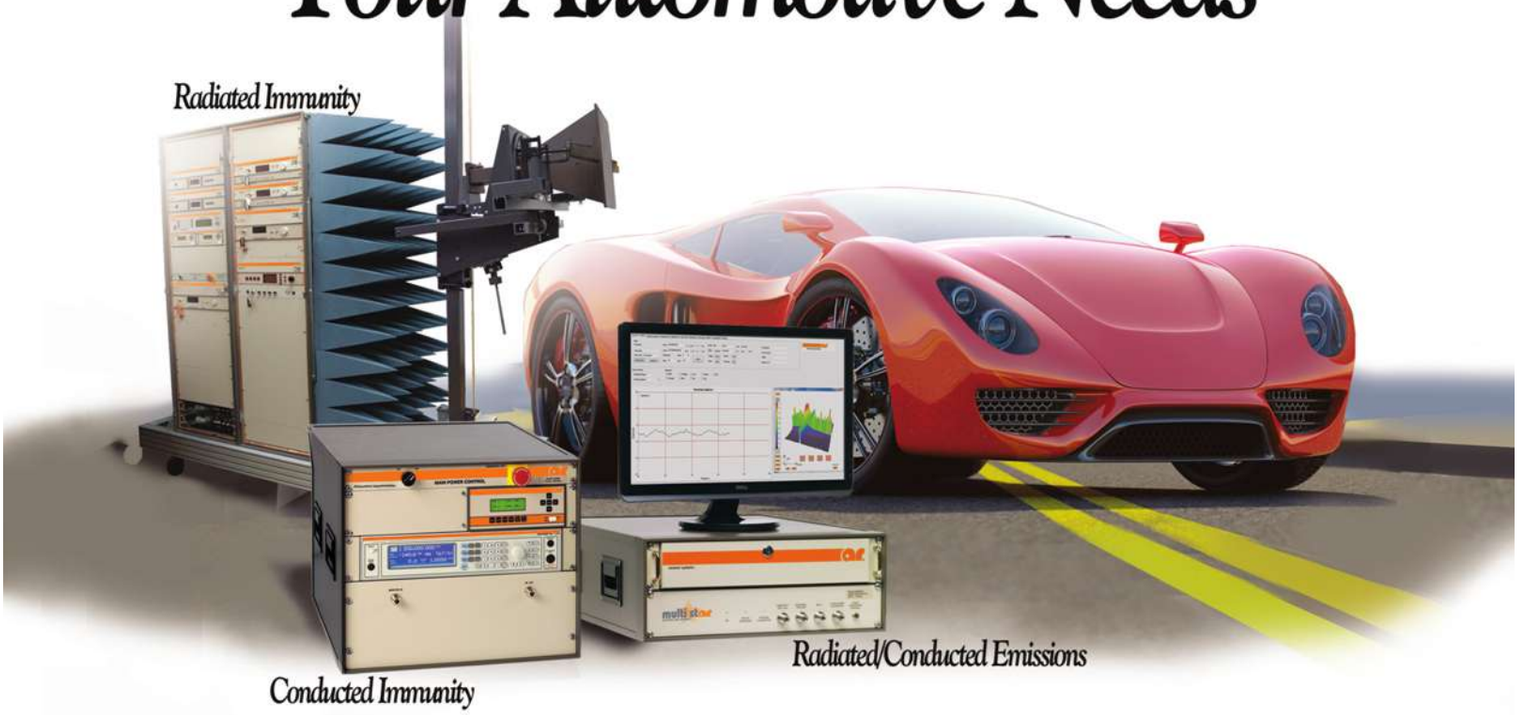

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FOCUS

A busy 2015 for SAEINDIA

Previously I wrote about the next orbit of growth toward the Vision 2020 set forth by the eminent galaxy of illustrious past leaders of **SAEINDIA**. Presidential Policies 2015 is slowly and steadily being translated into action by the programs and events carried out in the last three to four months.

The International Workshop on Integrated Vehicle Health Management for Aircrafts turned out to be a spectacular success in all respects. The support from industry and aerospace professionals including scientists and researchers was commendable. The event

Dr. Aravind Bharadwaj, President, SAEINDIA

also gave impetus to drive more activities under the Aerospace Board. The 5th anniversary celebration of the Aerospace Board was a logical extension with an assembly of captains and leaders from the aerospace industry to prepare the road map for the future.

Following the success of the Blue Ribbon CEO Conclave during former SAE President Mr. Daniel Hancock's visit, automotive roundtables on new product development were conducted in Chennai, Pune and Delhi. Each meeting witnessed an assembly of key stakeholders from the industry with very healthy and active interaction.

SIAT 2015 conducted in Pune touched a new high in terms of participants, exhibitors, delegates, sponsors, and papers presented.

The SUPRA SAEINDIA Virtual Competition held at Vel Tech University saw over 170 teams participating that were full of enthusiasm for the competition. The judges had a tough time deciding on the best 110 teams to compete in the final track competition.

SAEINDIA is planning to organize ITEC INDIA (International Transportation Electrification Conference India) 2015 along with the **IEEE** Industry Applications Society for the first time in India during August 2015. The theme for the event has been chosen as "Electrifying Mobility through Holistic Ecosystem Solutions." We seek active participation from all the members of SAEINDIA in terms of contributing technical papers. The abstract submissions are underway through the SAE My Tech Zone.

The 8th Edition of BAJA SAEINDIA was held at Pithampur, Indore in February and featured e-BAJA teams competing using ATVs with electric powertrains for the first time.

SAEINDIA is also organizing ICAM-3D Car Design Challenge in collaboration with **ESCI** (The Institution of Engineers at Chennai) in early February. The competition will inspire students to work on 3D printing, which can transform designs into tangible parts in one step without using conventional tools.

The Symposium on Fuels, Lubricants, Emissions and After-Treatment Devices is scheduled to be held on the 24th and 25th of April 2015 at New Delhi, which will be the cornerstone in the process of finalizing Auto Fuel Policy and Vision 2025.

We would like to publish more technical articles originating from India in the upcoming issues of *Mobility Engineering*. Therefore, we shall appreciate contributions from members of SAEINDIA by way of technical articles on the latest developments and advancements in the Indian automotive industry. Please send your contributions to Mr. Srinivas at dy.manager.project@saeindia.org.

We would like to place on record our appreciation for Mr. Shriramchandran, Deputy Director General, on his dedication and commitment, who is soon moving on from SAEINDIA. We also welcome Mr. G Vijayan, long-time professional member of SAEINDIA, who took over as Deputy Director General in February.

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SAEINDIA News

Top execs gathered at SIAT 2015

The biennial 3-day Symposium of International Automotive Technology (SIAT), now in its 14th iteration, along with SIAT Expo 2015 was a gathering of technocrats and members of the automotive fraternity from around the world. Automotive Research Association of India (**ARAI**) in association with Society of Automotive Engineers India (**SAEINDIA**), National Automotive Testing and R&D Infrastructure Project (**NATRiP**), and **SAE International** organized the event.

SIAT focused on the theme of "safer, cleaner, and quieter world" covering powertrain engineering, hybrid and electric vehicles, alternate fuels, vehicle and structural dynamics, ride and handling, emissions control, aftertreatment devices, emission inventory and ambient air quality, advanced electronics, materials and manufacturing, NVH (noise, vibration, and harshness), and modeling.

Mr. Anant Geete, Union Minister for Heavy Industries and Public Enterprises along with Mr. Vinod Dasari, President of ARAI and MD of Ashok Leyland, Mrs. Rashmi Urdhwareshe, Director, ARAI, and Mr. Ambuj Sharma, Additional Secretary to the Ministry of Heavy Industries and Public Enterprises, inaugurated SIAT 2015.

In his speech, Geete conveyed the need for the automotive industry to adopt the best practices and technologies. He also highlighted the importance of the "Make in India" initiative by the Indian Government and their ideas and suggestions on this initiative with respect to the automobile industry. He also added that Indian automotive is gradually going in the direction of global safety levels.

Attendees and guests stand at the entrance to SIAT 2015.

Mr. Dasari read a message from Prime Minister of India, Mr. Narendra Modi, to all attendees of the inaugural session saying, "The automotive sector has a key role to play in the Make in India initiative going forward." The Prime Minister gave his best wishes to the departments of SIAT 2015.

During the event, Geete also electronically inaugurated the new facility of ARAI at Chakkan, Pune, which will house the passive safety lab and is expected to start operations in the coming fiscal year. ARAI representatives also informed *Mobility Engineering* that they are in talks with the government to set up new standards for safety and for easing the development and manufacturing of electric vehicles (EVs) and hybrids (HEVs). According to ARAI's representatives, this work falls under a National Electric Mobility Plan (NEMP) and the Finance Ministry has so far sanctioned Rs 1,000 crores for the first two

Mr. Nitin Gadkari, Honorable Union Minister, North Government of India; Mr. M.C. Dathan, Director, Vikram Sarabhai Space Centre, Thiruananthapuram; Mrs. Rashmi Urdhwareshe, Director, ARAI; Dr. K.C. Vora, Senior Deputy Director, ARAI & Convener, SIAT 2015; and Mr. N.V. Marathe, Senior Deputy Director, ARAI were present on the valedictory function on 23rd January 2015.

A look inside the 2015 SIAT Expo.

Mr. Anant Geete, Mr. David Shutt, Mrs. Rashmi, and Mr. Vinod Dasari take part in the Lighting Ceremony.

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SAEINDIA News

The Baja SAEINDIA stall at SIAT Expo 2015

DR. K.C Vora speaks at SIAT 2015.

Mr. Nitin Gadkari and Mrs. Rashmi take part in the Valedictory function.

years to kick-start preliminary operations under this plan while the original requirement of funds for this plan was Rs 14,000 crores.

- The prominent highlight of SIAT 2015 was the roundtable discussion on "Fast Tracking the Evolution of Green Technologies in India" by Mr. David Hudson, Group Chief Engineer, **Tata Motors**, UK; Dr. Mathew Abraham, **Mahindra & Mahindra**; Dr. Gotthard Rainer, Vice-President, **AVL**; Mr. Mike Savage, Chief Engineer, **Drive System Design**, UK; Mr. DJ Kulkarani, Senior Deputy Director, ARAI; Mr. Chinmay Pandit, Director, Hybrid Solutions, **KPIT**; Mr. Thalavai Venkatesan, Head of Engineering, **Continental** (Automotive) India; and Mr. Shailendra Gosawami, Chairman and Managing Director, **Pushkaraj Group**.

Mr. Nitin Gadkari, Honorable Union Minister, North Government of India; Mr. M.C. Dathan, Director, **Vikram Sarabhai Space Centre**, Thiruananthapuram; Mrs. Rashmi Urdhwareshe, Director, ARAI; Dr. K.C. Vora, Senior Deputy Director, ARAI & Convener, SIAT 2015; and Mr. N.V. Marathe, Senior Deputy Director, ARAI, were present on the valedictory function on 23rd January 2015.

Dr. David Schutt, CEO, SAE International, said that the journey of knowledge and information will cross the boundaries of countries and continents. "The knowledge from SIAT will help professionals create a safer, cleaner, and quieter world," he concluded.

Mr. Rajan Wadhera, Vice President, ARAI and Chief Executive (Technology, Product Development & Sourcing & Member of the Group of Executive Board), Mahindra & Mahindra, proposed a vote of thanks.

R.Srinivasa Raghavan, SAEINDIA

Automotive roundtables held around India

The Chennai automotive roundtable event included industry leaders and was hosted by Mr. Prem from **Siemens**. Mr. Seshadri, SAE, welcomed the patrons and was followed by a keynote address from Dr. Arvind S. Bharadwaj, Mahindra & Mahindra Limited (M&M). The keynote speech threw good light on the expansion of Indian automotive into the global market, as well as touching on various approaches from M&M – MRV perspective. The following key points were made during the address:

- First time right and every time right
- Manufacturer and supplier must work in unison
- Scope creep.

The speech set the stage for the core panel discussion featuring Mr. Sharma, **Ashok Leyland**; Mr. Nageshwara Rao, **TAFE**;

Dr. Arvind S. Bharadwaj, M&M Limited, gives the keynote address in Chennai.

Mr. Seshadiri, SAEINDIA, delivers the welcome address at the automotive roundtable in Pune.

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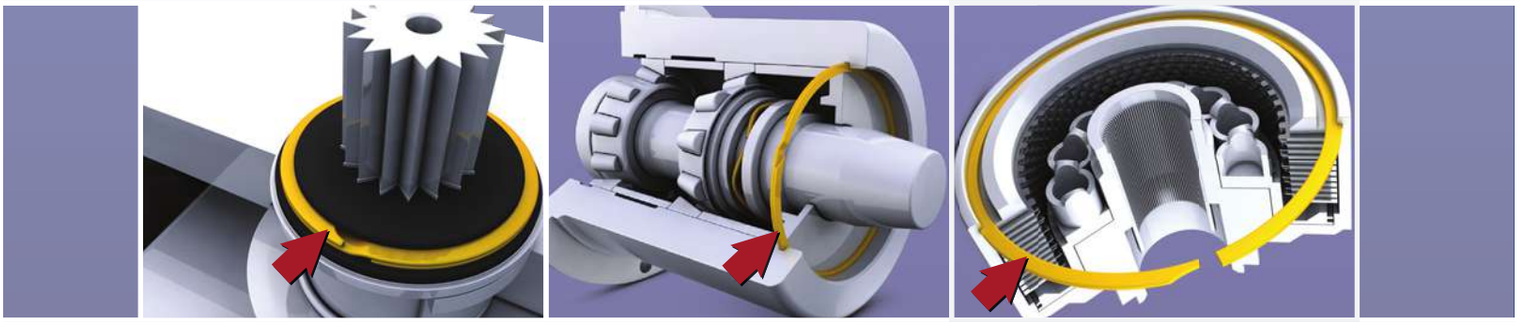

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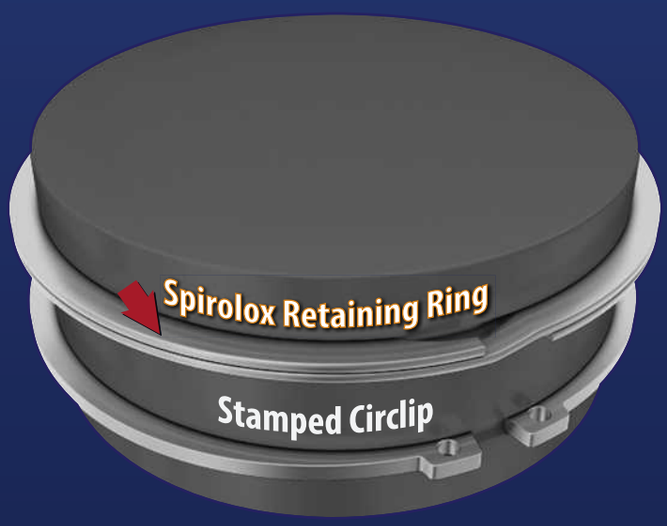

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SAEINDIA News

The crowd listens to the discussion during the Chennai automotive roundtable event.

The panel discussions provoked good responses from the audience in Pune, providing an interactive experience for those in attendance.

Mr. Sundar, **Rane Madras**; and Mr. Anirudha Takle, Siemens. The concentration of the discussion was toward RFQ to Cash.

The key points of panel discussions were:

- Design efficiency reduces with increasing iterations - Mr. Sharma
- Ability of design/scope changes without timeline change - Mr. Nageshwara Rao
- Importance of PLM tools in budget monitor - Mr. Nageshwara Rao
- Deployment of design standards and lean engineering approach - Mr. Sundar
- Golden thread approach (design to cost) - Mr. Anirudha.

The panel discussion was complemented by a healthy audience discussion. Key points were:

- RFQ to cash might not be the right approach (RFQ is too late already) - Lucas TVS personnel
- Engineering capacity understanding of the company - Lucas TVS personnel
- Stopping the reinventing of the wheel in a company - Mr. Anirudha
- Importance of change management - Mr. Meenakshi Sundaram, Hinduja Tech Ltd
- 'Product capability analysis by the designer' approach - Mr. Meenakshi Sundaram
- Learning in Management system (LMS) - Mr. Sundar.

The second automotive roundtable event in Pune attracted a much bigger gathering of delegates from various industries. Included in the panelists were Devajeet Sarkar, VP, Sourcing Supply Chain, M&M Trucks & Buses division; PK Banerjee, Head, Product Evaluation, Tata Motors; and Sanjay Kulkarni, Head, Vehicle Engineering, **Eaton**.

Mr. Gautam Gupta, Senior Director of Marketing, Siemens, started the discussion stating the future challenges for automobiles lie in the sophistication of automotive electronics.

The panel discussion was followed then focusing on RFQ to Cash conversion. The following were the key points discussed during the panel discussions:

- Product management across all technical centers across globe – PLM importance – Mr. Devajeet Sarkar
- Regulation driven industry – Modular design to cater to different market segments and regulation; complexity in program management and supplier management – Mr. PK Banerjee
- Defined system/process for collaboration and engagement – Mr. Sanjay Kulkarni
- Fool proof data sharing to supplier to avoid manufacturing failures; early involvement of suppliers in OEM product development for innovation – Mr. Gautam Gupta
- End of vehicle life and fleet modernization - Mr. PK Banerjee.

Innovation vs. cost variables was also discussed as well as supplier management for minimizing risk in product development. The panel discussions provoked good responses from the audience. The views and queries shared by the attendees were answered by the panelists, which made the event much more interactive.

The following were the key points from audience discussions:

- Reusability and recyclability of working parts from expired product
- Link between costing and supplier capability
- Estimated cost vs. actual cost, change management.

A final automotive roundtable was held in Gurgaon. Mr. Sandeep Bhatia introduced his team from Siemens to the gathering, which included renowned industry personnel and delegates. Mr. Raman from **Maruti** addressed the crowd by giving a brief note of the challenges and pressures the Indian auto industry has to face in the next decade due to the fall in average customer age and the corresponding rise in expectations, safety, emissions and the fuel regulations from the government in the next couple of years.

He then took the audience through a couple of examples from Maruti to highlight the importance of value for money of a product. He finished by giving a brief note on how a cost of a product is visualized in the RFQ, planned, and controlled during the entire product development stage.

Sandeep then introduced the panel consisting of Mr. Naveesh Garg, Mr. Shrinivas, and Mr. P.K Acharya. Mr. Gautama Dutta served as the moderator.

Dutta began the discussion by highlighting the top expecta-

Mr. C V Raman, Maruti, provides a briefing on the latest challenges for the auto industry at the automotive roundtable event in Gurgaon.

Dr. I V Rao, Maruti, speaks from the audience during the automotive roundtable in Gurgaon.

tions from the suppliers and the need of the transformation of current costing practices. The key discussion points were:

- Tracking operational and material cost simultaneously; capability development and reduction in outsourcing; maximal reuse - Mr. Naveesh Garg
- Proper visualization of customer requirements before quotation process; accounting factors that would affect product cost at the time of launch in the RFQ; challenges in costing for advanced engineering projects, which require lots of costing assumptions - Mr. Shrinivas
- Requirement of an organized costing group; need of trust between suppliers and OEMs involving better transparency - Mr. P.K Acharya.

The moderator took the discussion more turned to the audience for questions, which provoked good responses from those in attendance. The following were key highlights from the audience:

- Understanding the future requirements of the customer and setting the cost targets are necessary
- Enhanced transparency in costing considering profitability of both OEMs and suppliers is required.

Mr. Shreenath gave a small presentation on how to build transparency between suppliers and OEMs. He touched upon the need of integrating the schedule management to the PLM for creating transparency, tool costing reduction, and product cycle time reduction.

Shreenath summarized the discussion and gave the vote of thanks to all those who contributed to the event.

Mr.Meenakshi Sundaram, GM – Powertrain, Hinduja Tech, Chennai

Grand celebration marked SAEINDIA Aerospace Board's 5th anniversary

SAEINDIA Aerospace Board turned five years old on 17 December 2014. The Aerospace Board was established on 17 December 2009 in recognition of the increasing level of aerospace activities in India. The board consists of industry leaders from companies such as **Boeing**, **GE**, Eaton, **NAL**, **HCL SAFRAN**, and **HAL**. The group's objective is to develop a strong community of interest, leading to a healthy aerospace ecosystem in India.

The Aerospace Board, headed by Dr. Bala Bharadvaj, ensured that this day will not only provide members of the board with those moments to reminisce on, but also provide a platform to plan the next five years by brainstorming with the August members present. The board also announced key points, which will ensure rolling out measurable and qualitative activities. Bharadvaj started the day by introducing both the founding members & present board members of the Aerospace Board. Following the introductions, Mr. Damodaran shared milestones that were collaboratively achieved during the first five years.

Bharadvaj then interacted with the audience by introducing the concept of S.I.N.G.

S - Share your perspective

IN – on Industry Needs and/or India Needs

G – what can you "Give to the community" and want to "Get from the community."

Six groups were formed for discussions at the table on various topics of interest. This was followed up with one member from each team sharing their group's views, suggestions, recommendations, ideas, etc.

Bala Bharadvaj, Parvez Alam, Ravindra Naguri, Javaji Munirathnam, Vasanth Kini, and Damodaran Subramanian speak during the celebration of the 5th anniversary of SAEINDIA Aerospace Board.

Some of the key ideas presented by the different group representatives (Mr. Bejoy George, Mr. K.P Murthy, Mr. Prajol, Mr. Munirathnam, Mr. Naresh Palta, Mr. Kumar Subramaniam) are listed below.

- Establish a knowledge base of white papers, case studies, experts/ consultants available (national and international)
- Encourage skill development through aerospace activities in the form of lectures, competitions, events

SAEINDIA News

Members of the SAEINDIA Aerospace Board await the start of the 5th anniversary celebration.

- SAEINDIA to establish a mechanism to help students on aerospace related projects.
- SAEINDIA to play a key role in National Aerospace Policy
- Involvement of SAE in the National Skill Development Corporation's (NSDC) skill development activities
- Establish an aero modeling competition along the lines of Baja event.
- SAEINDIA to help create a testing and validation facility for the SME segment.
- SAEINDIA to find a way to leverage the very strong involvement in Indian automotive industry to assist with growth in aerospace
- Provide assistance to enhance the interaction between R&D labs, academicians, industry leaders, and students on aerospace.
- Increase involvement in SAE standards development board
- Need for more entry level competition for school children on aero modeling in line with AWIM

The evening ended with a dinner hosted by the Aerospace Board.

Dr. K. Bala Bharadvaj, Chair, Aerospace Board

Workshop on integrated vehicle health management held in Bangalore

SAEINDIA and its Aerospace Board hosted a daylong international workshop on Integrated Vehicle Health Management (IVHM) on 17 October 2014 in Bangalore with experts from around the world.

Pioneers working in the field of IVHM define it as "the unified capability of a system of systems to assess the current or future state of the member system health and integrate that picture of system health within a framework of available resources and operational demand."

The goal of IVHM is to maintain complex systems so that they can deliver their stated performance requirements by reducing life-cycle costs and not compromising on safety. It aims to do this by implementing optimal maintenance actions that are based on information gathered from the asset itself and from its operational and maintenance history, integrated with appropriate system models and with knowledge of the maintenance and repair supply chain.

The five key phases of the IVHM process as shown in Figure 1 are: Sense, Acquire, Transfer, Analyze, and Act. Data is acquired from the asset (possibly from the logistics supply chain in the future) via sensors that are either embedded or are installed during maintenance. Transfer of data is accomplished via existing wired communication links or wireless. Analysis functions consists of algorithms that correct, scale, normalize and analyze the data, compare it with expected values obtained from detailed system models, and make maintenance decisions based on deviations from the

Figure 1. Overview of the main elements of an IVHM system. (IVHM Centre, Cranfield University)

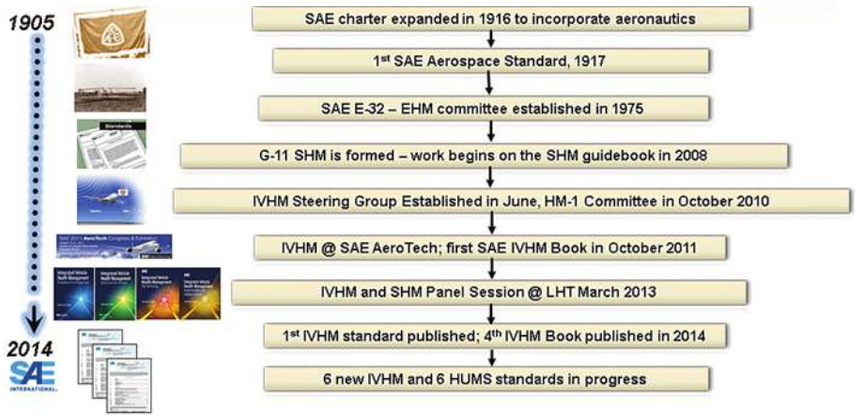


Figure 2. SAE's journey with respect to IVHM.

Richard Greaves, President of SAE International (right), and David Alexander, SAE Europe, give the history of SAE and its involvement in aerospace activities.

Dr. Ravi Rajamani, Meggitt, USA, talked about state-of-the-art engine health management.

norm. The appropriate advice (Action) is then given to the maintainer to take the needed action. This advice will clearly engender further actions that affect the MRO (maintenance, repair, and overhaul) supply chain.

The workshop at Bengaluru consisted of four plenary talks and practical demonstrations, and concluded with a series of panel sessions on various aspects of EHM and IVHM.

Mr. Richard Greaves, President of SAE International, started off the proceedings with a concise history of the SAE and its involvement in aerospace activities. Mr. David Alexander, **SAE Europe**, followed this up with an exciting audio-visual, interactive demo of a new website, and then Mr. Ian Jennions, **Cranfield University**, gave a comprehensive introduction to IVHM. Finally, Dr. Ravi Rajamani, **Meggitt**, USA, talked about state-of-the-art engine health management (EHM). The highlight of the session was a live demonstration of Boeing's Aircraft Health Management (AHM) system by Mr. Dave Kinney from Boeing, Mr. Steve Heath from **Etihad Airlines**, and Mr. Sameer Buch from **Jet Airways**.

K. S. Ramprasad from GTRE moderated the first panel discussion on Engine Health Management. The panelists were Bharatan Aravamudhan, **Honeywell**; Lachanna Arsha, **Cyient**; Alexandre Belli, **Air France/KLM**; Duncan Chase, **Rolls-Royce**; Gene Iverson, Boeing; and D. Umamaheshwar, GE.

Kota Harinarayana from **ADA** moderated the second panel on Integrated Vehicle Health Management. The panelists were Richard Greaves, Meggitt; Amit Patra, **IIT** Kharagpur; KallappaPattada, Boeing; G. V. V. Ravikumar, **Infosys**; K. Vijayaraju, ADA; and Rhonda Walthall, **UTAS**.

A. R. Upadhya from ADA moderated the third panel on Practical Aspects of IVHM. The panelists were Prashant Bhadoria, HAL; David Fontaine, UTAS; S. Gopalakrishnan, **IISc**;

The workshop at Bengaluru consisted of four plenary talks and practical demonstrations, and concluded with a series of panel sessions on various aspects of EHM and IVHM.

The IVHM panel discussion. From left to right: Kallappa Pattada, Boeing; Richard Greaves, Meggitt; Rhonda Walthall, UTAS; Kota Harinarayana, ADA; GVV Ravikumars, Infosys; K Vijayaraju, ADA.

The panel discussion on the practical aspects of IVHM. From left to right: Prashant Bhadoria, HAL; David Fontaine, UTAS; S. Gopalakrishnan, IISc; A.R. Upadhya, ADA; Steve Holland, GM; Tim Wilmering, Boeing.

Steve Holland, **General Motors**; and Tim Wilmering, Boeing.

Prakash Mangalgiri of ADA moderated the final panel on Complex Systems and Application of IVHM in India. The panelists were Dinakar Deshmukh, GE; Satish Mohanram, **National Instruments**; P Sivasankaran Nair, NAL; Amit Patra, IIT Kharagpur; and Madhusudhan Varadaraj, Siemens.

At the conclusion of the panels, David Alexander summed up the day by thanking all the participants and encouraging the audience to actively participate in SAE activities. The events of the day were brought to a gracious close by the co-chair of the conference, Dr. Bala Bharadvaj from Boeing, who thanked all the volunteers, especially D. Seshadri and his dedicated team of volunteers from SAEINDIA, the local students, the Workshop Steering Committee, and the SAEINDIA Aerospace Committee, who worked diligently on making this event a success.

Dr. Ravi Rajamani, Meggitt, USA

SAEINDIA News

Electric vehicles added to Baja SAEINDIA

The 8th Baja SAEINDIA was scheduled to be held at NATRiP, Pithampur from 19th-22nd February 2015. It is an event where the engineering college student teams are tasked to design and build an all-terrain off-road vehicle as per guidelines provided in terms of construction and safety. Baja has now become a big brand with initiatives of SAEINDIA and ARAI.

Mahindra & Mahindra will once again be the principal sponsor of the event and will be joined by sponsors ARAI, **Altair**, **ANAND Group**, **ANSYS**, AVL, **Briggs and Stratton**, **Bharat Petroleum**, **Cummins**, Eaton, **Emitec**, **Endurance**, **FIAT**, General Motors, **iCAT**, **John Deere**, NATRiP, and **Varroc**.

New this year are stricter rules and more difficult test tracks to take the event to an international level. International teams have been invited to compete on the Indian tracks, a first for Baja SAEINDIA. This year's event will introduce a new high-speed endurance track of larger spread and more hurdles. Tracks like suspension and traction, and maneuverability are now modified to a better extent. 110 teams from all over India will compete on the same track.

This year SAEINDIA is also introducing eBaja, where 10 teams from all over India will take part. The electric vehicles will run with the same power as combustion engines and will share the same track as the main event. A technical student workshop by **MReva** and the efforts of the SAEINDIA organizing committee will make the event a success.

The workshops have students well prepared as they are giving the final mold to their vehicle with their finalized designs. Additionally, they are going to face technical inspection in their college.

Expert discussed engine failure investigation and analysis

SAEINDIA along with SAE International organized a seminar on "Engine Failure Investigation and Analysis" by Mr. Robert Kuhn, on the 1st and 2nd of December 2014 in Chennai and the 4th and 5th of December 2014 in Pune. Kuhn is an expert with years of experience and demonstrated his expertise on the subject. He is also part of the eminent panel of SAE in the international lecture circuit.

Engines can and do experience failures in the field in a variety of equipment, vehicles, and applications. On occasion, a single vehicle type or equipment family will even experience multiple engine failures leading to the inevitable need to determine what the most likely cause of one or all of those failures was. This comprehensive seminar introduced participants to the methods and techniques used to determine the most likely cause of an individual engine or group of engine failures in the field. The seminar began with a review of engine design architecture and operating cycles, integration of the engine into the vehicle itself, and finally customer duty cycles and operating environments. Special emphasis was placed on the number and type of subsystems that not only exist within the engine (diesel and gasoline) but also are used to integrate the engine into the overall vehicle package. Following this review, participants learned about failure types, investigation techniques, inspection methods, and how to analyze the available evidence using their own knowledge of engine and vehicle operating characteristics to determine the most likely cause of an engine failure. The seminar concluded with a review of actual engine failure case studies that were investigated and resolved using the same process and methods taught during the course.

Seminar held on evaporative emission control

SAEINDIA along with SAE International organized a seminar on "Evaporative Emission Control" by Dr. Sam Reddy, on the 9th and 10th of December 2014 in Delhi, the 12th and 13th in Bangalore, and the 23rd and 24th of December in Pune. Dr. Reddy is an acknowledged expert on the subject with years of experience in the field.

Reddy is currently working as a Director, **Deltronix USA**, Inc. He was a Technical Fellow at GM Research and Development Center. He holds 26 U.S. patents and several more are pending. He has authored 11 SAE papers in the same field. He is the recipient of three GM R&D Charles L. McCuen Special Achievement Awards, two GM Boss Kettering Awards, and the 2004 SAE Environmental Excellence in Transportation Award.

This comprehensive training class introduced the participants to the principles of gasoline evaporative fuel vapor generation (diurnal, hot soak, running loss, and refueling) from the vehicle fuel tank, fuel vapor storage in activated carbon canisters, and fuel vapor purging (desorption) and consumption in engine combustion. The training class began with an analysis of gasoline and gasoline/ethanol blends and estimation of their vapor pressures and vapor generation. In-depth analysis of various fuel vapor generations as a function of fuel properties (ethanol content, Reid Vapor Pressure, etc.) and ambient conditions were presented. Activated carbon canister design, OBD II leak detection, hydrocarbon permeation, and Euro5/6, CARB and EPA evaporative test procedures were also covered. Participants had the opportunity to apply the knowledge gained by solving numerous practical problems and helped in designing a sample evaporative and refueling emission control system.

Volvo CE transfers backhoe loaders and motor graders manufacture to SDLG

Volvo Group announced in late 2014 that **Volvo Construction Equipment** will discontinue development and production of backhoe loaders and motor graders in Europe and the Americas and will transfer these operations to its Chinese company, **SDLG**. SDLG has been present in India since 2009. Combined with other efficiency enhancement measures, this move by Volvo will result in a workforce reduction of about 1000 employees.

Volvo says that SDLG-branded backhoe loaders and motor graders will better serve customer demands in the large and growing value segment of the market.

Currently, motor graders are built at Volvo CE's production sites in Shippensburg, U.S., and Pederneiras, Brazil, while backhoe loaders are manufactured in Pederneiras, Brazil, and Wroclaw, Poland. Ceasing European production of backhoe loaders will result in the closure of Volvo CE's operations in Wroclaw. According to Volvo, the current product lines of technologically advanced and high-spec Volvo-branded backhoe loaders and motor graders have addressed a relatively small premium segment of the market. SDLG-branded backhoe loaders and motor graders will better serve customer demands in the large and growing value segment of the market. The measures within Volvo CE are a part of the series of new activities within the increased scope of the Group's Strategic Program 2013-2015, which was published in conjunction with the report on the third quarter 2014. Combined, these activities are expected to reduce the Group's structural costs by SEK 3.5 billion (440 million USD).

Maruti Suzuki refines Swift engine for 10% FE gain

Maruti Suzuki's recent refresh of the Swift resulted in a 10% improvement in the car's fuel efficiency, owing largely to powertrain refinements. With a certified fuel efficiency of 25.2 km/L, up by 10%, the Swift Diesel is powered by the 1248cc DDiS 190 compression-ignition engine returning a claimed 190 N·m (140 lb·ft) at 2000 rpm and 75 ps (55 kW) at 4000 rpm. The Swift Petrol, with a 9.67% FE improvement at a certified 20.4 km/L, features a 1197cc K series VVT gasoline engine that delivers 84 ps (62 kW) at 6000 rpm and 115 N·m (85 lb·ft) at 4000 rpm. Among the innovations by Maruti and Suzuki engineers to improve fuel efficiency include changes in engine hardware leading to improved thermal efficiency, reduced frictional losses, and changes in engine calibration. The compact combustion chamber and higher compression ratio on the gasoline engine helps to improve engine efficiency, while the advanced thermal management system along with low friction engine oil and a modified fuel-injection system help the diesel engine in faster warm up and lower frictional losses, according to the company.

Maruti and Suzuki engineers improved the Swift's fuel efficiency via changes in engine hardware leading to improved thermal efficiency, reduced frictional losses, and calibration changes.

VISTARA signs contract with Airbus to support A320 fleet

VISTARA, a new carrier based in New Delhi, has signed long-term Flight Hour Services Tailored Support Package (FHS-TSP) contracts with **Airbus** with the entry into service of its 20 A320 leased fleet.

New Delhi-based VISTARA's Flight Hour Services Tailored Support Package (FHS-TSP) contracts with Airbus will provide integrated and guaranteed services for this carrier's leased A320 fleet.

The FHS-TSP contract provides an integrated and guaranteed service ranging from components supply and repair to full airframe maintenance and engineering service. An on-site Airbus team will manage daily maintenance activities (e.g., spares, warehousing, line, engineering, checks) ensuring VISTARA can maintain the highest aircraft technical dispatch and operations.

This latest selection by VISTARA marks an important step in Airbus' FHS strategy to play a major role in the A320 maintenance market by providing innovative and competitive solutions.

"This long-term commitment recognizes our confidence in Airbus to deliver the highest quality service," said Rajender Singh, Senior Vice President Engineering of VISTARA. "Having the aircraft manufacturer supporting our aircraft inventory, maintenance, and engineering is the most comprehensive solution for our operational readiness from day one."

According to Didier Lux, Executive Vice President, Customer Services at Airbus, VISTARA is Airbus' first FHS customer in India. "This is a real endorsement which confirms operators' satisfaction and value in having Airbus' FHS-TSP turnkey

Industry NEWS

solution," he said. "Our FHS team is committed to deliver the best possible service to VISTARA."

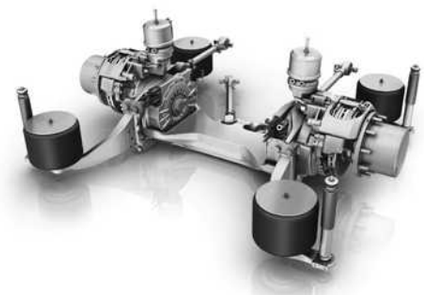
Airbus' FHS now covers more than 150 aircraft with operators of A320, A330, and A380 fleets.

VISTARA is the name of the joint venture between India's **Tata Sons** and **Singapore Airlines**. The new carrier, announced in 2013, will be a full-service airline based in New Delhi.

ZF wins innovation award for electrically driven city bus axle

As part of the "International busplaner Sustainability Prize 2015," an independent jury of experts assessed bus innovations that combine economic success with social responsibility and environmental friendliness. In the "Components" category, **ZF**'s AVE 130 electric portal axle ultimately took the top prize. The ZF innovation paves the way for lane-independent low-floor city buses, which are powered with various hybrid configurations or even entirely electrically—and hence locally zero-emissions. This is primarily due to two 120-kW electric motors integrated directly in the axle. The latest AVE 130 also boasts new gearing geometry and quieter running.

In various field trials over the past few years, more than 300 ZF electric portal axles have already logged over 10 million km (6 million mi). Some of those trials included articulated buses manufactured by **EvoBus** in which the AVE 130 is used in serial hybrid operation—i.e., in conjunction with a downsized diesel generator. ZF says that due to the optimum design of the overall system, it can provide fuel savings of up to 30% compared with conventional diesel drives.



In various field trials over the past few years, more than 300 ZF AVE 130 electric portal axles have logged over 10 million km (6 million mi). It is shown here in its latest development version.

At present, a large number of customer projects are involved in trials or are about to be implemented worldwide—for instance in China with the manufacturer **Foton** and in Turkey with **Bozankaya** where the AVE 130 is being used in battery-electric buses and "can leverage all the benefits of electromobility."

Other advantages of the axle arise in relation to vehicle design because the AVE 130 is installation-compatible with ZF's AV 132 and AVN 132 portal axles and its electric motors are directly located in the hub units of the axle. As the conventional drive and propshaft in the rear are no longer needed, the installation space for seats and standing room can be expanded, the passenger area can have a completely level aisle, and the low-floor technology provides for a stepless entry and exit.

Jet Aviation Basel gains DGCA approval from India for Dassault aircraft

Jet Aviation Basel recently received CAR-145 approval from the Director General Civil Aviation (DGCA) in India to provide full maintenance services to Indian-registered **Dassault** Falcon 7X, Falcon 900 (series), and Falcon 2000 (series) aircraft. With this regulatory approval, Jet Aviation Basel is authorized to perform line and base maintenance on Falcon 7X, Falcon 900 series, and Falcon 2000 series aircraft that are registered in India.

Jet Aviation Basel recently received CAR-145 approval from the Director General Civil Aviation in India to provide full maintenance services to Indian-registered Dassault Falcon 7X, Falcon 900 (series), and Falcon 2000 (series) aircraft.

"As an Authorized Service Center for Dassault Falcon aircraft, this is a significant service extension for owners and operators of Dassault Falcon 7X, 900, and 2000 aircraft that are registered in India," said Johannes Turzer, Vice President and General Manager of the Jet Aviation Basel Maintenance Center. "This approval recognizes our ability to meet their maintenance requirements to the highest standards, and we look forward to welcoming these customers to our Basel facility."

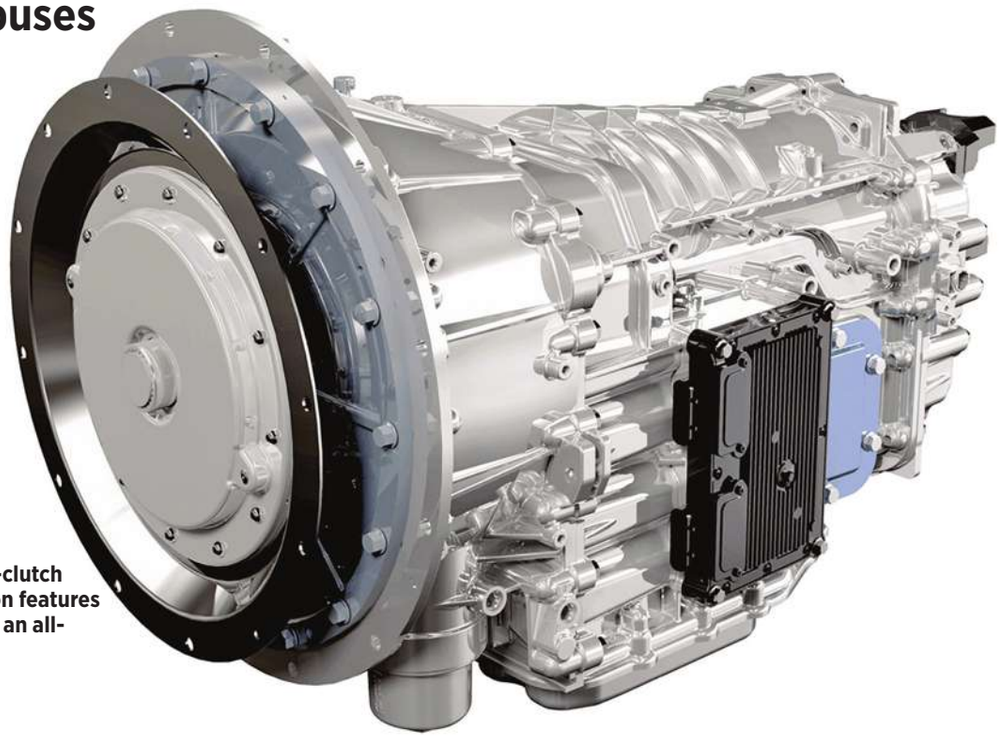
Jet Aviation Basel is a factory-approved service center by **Airbus**, **Boeing**, **Bombardier**, Dassault, and **Gulfstream**. The facility has in-house design and engineering departments, along with on-site cabinetry, upholstery, fiberglass, and paint shops. The organization is capable of outfitting jets as large as an Airbus A380 or the Boeing 747-8 series.

Tech Mahindra launches aftermarket platform for predictive maintenance

Tech Mahindra Ltd. recently launched its Automotive Aftermarket Suite, which enables the company to offer solutions in telematics and sensor-based predictive maintenance for thousands of cars on the road worldwide. Tech Mahindra plans to provide this scalable solution as a managed service to OEMs, importers, and dealer networks. Features of the Automotive Aftermarket Suite include real-time transparency to vehicle owner on vehicle health status, integrated process for predictive maintenance and pro-active service appointment, and a dedicated portal used by the dealer with all vehicle activities, warnings, faults, and service history. Tech Mahindra plans to launch this platform solution in Europe and U.S. markets initially, gradually expanding to other regions. "This is a platform offering that truly demonstrates the end-to-end nature of the Connected World and Connected Solutions theme, combining our capabilities in Product Engineering Enterprise Mobility, Infrastructure Hosting, BI and Analytics, and underscores our leadership in Automotive and Telecom verticals," said Karthikeyan Natarajan, Global Head – Integrated Engineering Services, Tech Mahindra.

TRUCK POWERTRAIN

Eaton unveils DCT for medium-duty trucks and buses



Eaton's Procision dual-clutch automated transmission features seven speeds and uses an all-aluminum casing.

Trucks were some of the first vehicles to adopt automated manual transmission systems in the 1980s, and **Eaton** was among the first transmission suppliers to launch such a system with its Semi Automated Manual Transmission. Cost and additional complexity have been likely factors in lower levels of interest in a dual-clutch automated system, but Eaton has now released details of its Procision dual clutch transmission, unveiled this fall at the IAA Hanover truck show, aimed at middleweight trucks and buses up to 16-t gross vehicle weight.

The transmission features seven speeds and uses an all-aluminum casing. It is electronically controlled and hydraulically activated. Following established dual-clutch practice, the system changes gear by switching between clutches to engage a pre-selected gear. Synchronizer rings are used to aid gear-shifting.

According to Tony Truelove, Global Truck Marketing Communications Manager at Eaton, the transmission is a direct competitor to the torque converter automatic **Allison** 2000 series.

"The largest primary advantage is fuel economy," said Truelove. "Up to 8 to 10% improvement over the latest-generation torque converter automatic. The transmission has adjustable forward and reverse creep mode, enabling a much slower pace than an equivalent torque converter automatic. We also have a feature that we call Hill Helper, which holds the dual-clutch mechanism on gradients up to 8% at 26,000 lb (11,800 kg) for up to three seconds."

The Procision transmission uses a wet clutch system and the transmission needs one type of oil for the entire unit. An oil cooling system is used to help extend operating life. The dual-clutch module is completely contained within the transmission casing. Torsional vibrations are controlled using a five-spring damper. This is sealed with the aim of eliminating contamination. New synthetic oil enables oil and filter change intervals of 150,000 mi (240,000 km). Eaton says that the internal sump filter and electrical system do not require maintenance.

The transmission control module is mounted on the transmission casing and all wiring is contained within the casing, helping to ensure that wiring is not vulnerable to external damage.

Transmission features include Eaton Dynamic Shifting, a software mode that permits the transmission to shift automatically between "economy" and "performance" gear change schedules, according to weight, gradient, and demand from the driver. Eaton claims that economy and performance shift modes can be adjusted to customer requirements.

Procision also features brake pedal-actuated Tap Down Shifting, which enables downshifting on gradients or in other circumstances without the driver removing his or her hands from the steering wheel. Similarly, when the transmission is in Low mode, Automatic Grade Braking is actuated to reduce speed on long steep gradients, by automatically downshifting.

The transmission offers a choice of three power takeoff points and these can be activated altogether or individually from the factory, by a dealership, or by subsequent owner if not previously activated.

Initial production will be aimed at North America, but Procision will be produced for other markets when there is demand. The transmission will be available in North America starting July 2015.

John Kendall

ENERGY

Stanford scientists create a smart lithium-ion battery that warns of potential fire hazards

As the use of lithium-ion batteries continues to expand into millions upon millions of cellphones, laptops, and other electronic devices, their use is growing as well in automotive and aircraft applications.

But not without some setbacks. Prior to more widespread use in the mobility industry, around 2006 **Sony** recalled millions of lithium-ion batteries after reports of double-digit laptop fires. According to Sony, during the manufacturing process tiny metal impurities had gotten inside the batteries, causing them to short-circuit.

Closer to home and more recent, last year **Boeing** was forced to temporarily ground the 787 fleet in no small part because battery packs in two airplanes overheated and/or caught fire. Though the packs were redesigned, the cause of the fires has yet to be determined.

That said, **Stanford University** scientists are working on a "smart" lithium-ion battery that they hope will at least provide ample warning before it overheats.

"Our goal is to create an early-warning system that saves lives and property," said Yi Cui, Associate Professor of Materials Science and Engineering. "The system can detect problems that occur during the normal operation of a battery." Cui added that "normal operation" does not apply to batteries damaged in a collision or other accident.

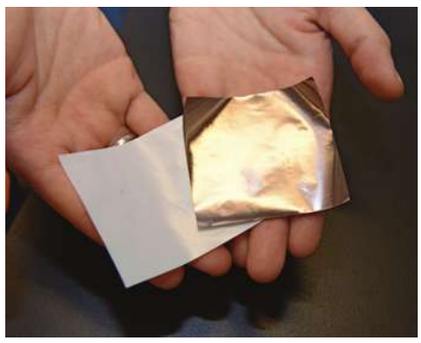
Cui said that the likelihood of a bad thing such as a battery fire are "maybe one in a million. That's still a big problem, considering that hundreds of millions of computers and cellphones are sold each year. We want to lower the odds of a battery fire to one in a billion or even to zero."

A typical lithium-ion battery consists of two tightly packed electrodes—a carbon anode and a lithium metal-oxide cathode—with an ultrathin polymer separator in between. The separator keeps the electrodes apart. If it's damaged, the battery could short-circuit and ignite the flammable electrolyte solution that shuttles lithium ions back and forth.

The separator is made of the same material used in plastic bottles. It's porous so that lithium ions can flow between the electrodes as the battery charges and discharges.

Manufacturing defects, such as particles of metal and dust, can pierce the separator and trigger shorting, as Sony had discovered. Shorting can also occur if the battery is charged too fast or when the temperature is too low, known as overcharge.

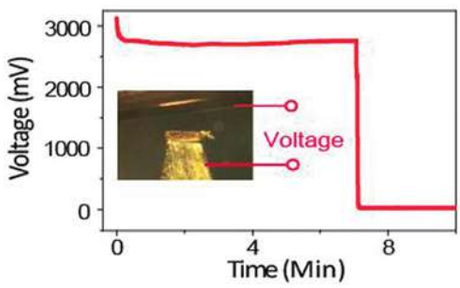
"Overcharging causes lithium ions to get stuck on the anode and pile up, forming chains of lithium metal called dendrites," said Cui. "The dendrites can penetrate the porous separator and eventually make contact with the cathode, causing the battery to short. In the last couple of years we've been thinking about building a smart separator that can detect shorting before the dendrites reach the cathode."



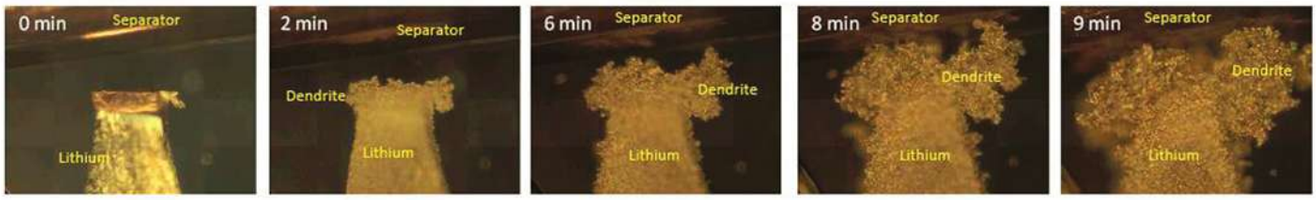
The ultrathin copper sensor is deposited atop a conventional battery separator (white square) as part of an early warning system to alert users that a lithium-ion battery is overheating. (Mark Shwartz, Precourt Institute for Energy, Stanford University)

To address the problem, Cui and his colleagues applied a nanolayer of copper onto one side of a polymer separator, creating a novel third electrode halfway between the anode and the cathode.

"The copper layer acts like a sensor that allows you to measure the voltage difference between the anode and the separator," said Densy Zhuo, a graduate student under Cui. "When the dendrites grow long enough to reach the copper coating, the voltage drops to zero. That lets you know that the dendrites have grown halfway across the battery. It's a warning that the battery should be removed before the dendrites reach the



A lithium anode and separator-wrapped lithium counter electrode with copper conductive layer facing the lithium anode housed in a glass cell for in-situ optical microscopy observation. During charging of the cell, non-uniform deposition of lithium onto the lithium electrode leads to mossy dendrite formation and growth on the surface. The lithium dendrites make contact with the conductive copper layer on the separator at about 6–8 min, giving rise to a 3-V drop as the potential difference between copper and lithium is dissipated on contact. (Hui Wu, Stanford University)



cathode and cause a short circuit."

The buildup of dendrites is most likely to occur during charging, not during the discharge phase when the battery is being used.

"You might get a message on your phone telling you that the voltage has dropped to zero, so the battery needs to be replaced," Zhuo said. "That would give you plenty of lead time. But when you see smoke or a fire, you have to shut down immediately. You might not have time to escape. If you wanted to err on the side of being safer, you could put the copper layer closer to the anode. That would let you know even sooner when a battery is likely to fail."

In addition to observing a drop in voltage, researchers were able to pinpoint where the dendrites had punctured the copper conductor simply by measuring the electrical resistance between the separator and the cathode. The location of the tiny puncture holes was confirmed by actually watching the dendrites grow under a microscope.

"The copper coating on the polymer separator is only 50 nanometers thick, about 500 times thinner than the separator itself," said Hui Wu, a postdoctoral fellow in the Cui group. "The coated separator is quite flexible and porous, like a conventional polymer separator, so it has negligible effect on the flow of lithium ions between the cathode and the anode. Adding this thin conducting layer doesn't change the battery's performance, but it can make a huge difference as far as safety."

Most lithium-ion batteries are used in small electronic devices. "But as the electric vehicle market expands and we start to replace onboard electronics on airplanes, this will become a much larger problem," said Zhuo.

"The bigger the battery pack, the more important this becomes," said Cui. "Some electric cars today are equipped with thousands of lithium-ion battery cells. If one battery explodes, the whole pack can potentially explode."

The early-warning technology can also be used in zinc, aluminum, and other metal batteries. "It will work in any battery that would require you to detect a short before it explodes," Cui said.

Jean L. Broge

AVIONICS

AFRL, ThermAvant collaborate on technologies to help electronics stay cool

A ThermAvant employee is shown testing the company's oscillating heat pipe thermal management solution.

A next-generation, micro-chip carrier for cooling is currently in development by Columbia, MO-based **ThermAvant Technologies**, LLC, and is already being tested by manufacturers of several major commercial and military satellite and aerospace systems, according to the company. This cooling solution will reduce the temperature of high-power satellite components to levels manageable by the spacecraft's thermal control system, which is beneficial because it improves processor reliability, while providing the opportunity to increase on-board processing,

The **Air Force Research Laboratory** (AFRL) and ThermAvant began researching the application of this technology as a result of an Air Force Small Business Innovation Research (SBIR) solicitation. The project called for reliable, high-conductivity heat spreaders; ThermAvant demonstrated the improved heat transfer properties of different structural materials (including aluminum, titanium, copper, and a copper molybdenum composite) embedded with oscillating heat pipe (OHP) technology. OHP-embedded chip carriers and heat spreaders will be used to transport heat dissipated by micro-chips to the spacecraft's larger thermal control systems.

This is a critical technology for space-based systems that will enable the deployment of higher temperature and power processors aboard satellite payloads. It can be used in both commercial and military satellite applications, as well as any high-performance land-based electronics. ThermAvant previously investigated the thermal performance tradeoffs of different fabrication processes for making OHP heat spreaders under a range of simulated real-world operating conditions. The company was co-founded by Dr. Bill Ma, a Professor of Mechanical Engineering at the **University of Missouri**.

During the testing, ThermAvant's prototype OHP-embedded heat spreaders provided an 84% reduction in the temperature rise across the heat spreader,

when compared to current state-of-the-art technologies. This reduction in temperature provides many benefits, but the most important is the ability to increase the onboard computing power.

Current satellite processors are running at 10% of their operating capability as a result of insufficient thermal management. Reducing the junction temperature allows for increased processing capability (up to 10 times more) and increases the expected lifetime of the onboard chips. Additionally, the advanced manufacturing techniques developed under this effort will allow this higher-performing technology solution to be manufactured at a lower price point than competing technologies.

The company's improved methods for making OHP-based products has already demonstrated commercial promise to both space- and ground-based thermal management applications for electronics. During the first year of this Phase II SBIR, ThermAvant transitioned OHP-based thermal management solutions to four major defense contractors for six applications on platforms ranging from Army tanks to Navy ships and Air Force aircraft and spacecraft. In these applications the OHP-based thermal management solution performed 5% to 50% better than the status quo, and is on average approximately 20% less expensive.

The Air Force SBIR and Small Business Technology Transfer (STTR) programs are mission-oriented programs that integrate the needs and requirements of the Air Force through research and development topics that have military and commercial potential. The SBIR and STTR programs provide more than $300 million in funding for R&D activities by small businesses annually, from the early stages of concept development until it transitions to military or commercial use.

Jean L. Broge

OFF-HIGHWAY ELECTRONICS

Danfoss introduces robust telematics platform

The Danfoss Telematics Solutions is applicable to any application, allowing OEMs to implement telematics features that customers request without the need for specific programming knowledge.

"Telematics has become a megatrend in heavy equipment industries as more and more companies see value in having a 24/7, real-time overview of their fleet," according to Marco Tacke, Product Marketing Manager of Telematics Solutions at **Danfoss**.

Danfoss engineers have drawn on more than 30 years of experience in electronics and applications know-how to develop Danfoss Telematics Solutions, an easy-to-integrate telematics platform for either new off-highway equipment or existing fleet retrofits. Danfoss says that while other telematics solutions offer bits and pieces of capability, its new system design offers a comprehensive suite of telematics as an all-in-one system.

The system combines machine-integrated technology, satellite, and cellular network connectivity, and a customizable, intuitive user interface to give fleet owners visibility of how, when, and where their equipment is used. It uses a powerful and versatile IT infrastructure and Web-based interface to gather, transmit, interpret, and store data that is most valuable to the end user. The customizable interface is easy to use and accessible on mobile devices such as smartphones and tablets.

Through use of the Danfoss PLUS+1 platform, OEMs can implement telematics features without the need for specific programming knowledge. The PLUS+1 platform also makes retrofitting equipment as simple as replacing a cable without the need to change a single line of software code.

"Danfoss Telematics Solutions offer our OEM customers the opportunity to 'plug-and-perform' rather than 'code-and-compile,'" said Tacke. "This saves significant time and cost during development, enabling customers to focus on their core competencies."

A short list of the capabilities of the system include data analysis, remote diagnostics, remote change of system parameters, remote software updates, geofencing, and automated report generation.

The Danfoss Telematics Solutions WS403 unit, which is the first release of the platform.

The WS403 unit integrates seamlessly in new or existing equipment as the platform is an open and flexible solution that can be expanded as telematics capabilities continue to evolve.

"Operations can use this data flow to better manage maintenance, minimize downtime, allocate resources, and protect equipment," Tacke said.

The Danfoss Telematics Solutions platform is open and flexible, allowing OEMs to create custom applications and services, integrating seamlessly with the PLUS+1 development and service tools, allowing for real-time remote access to applications. All PLUS+1 service tool features are available for connected machines, allowing for adjustments to PLUS+1 application parameters or updates to PLUS+1 software.

"Danfoss Telematics Solutions were engineered with the future in mind," Tacke said. "Our platform has the power and capacity to expand as telematics capabilities and needs continue to evolve. Our initial offering, the WS unit, is only the first release from the platform. We will continue to introduce robust telematics solutions."

Danfoss Telematics Solutions offer compliance with Global System for Mobile (GSM) wireless communication and GPS technology, meaning every Danfoss telematics unit will function anywhere in the world. This flexibility comes with the speed and performance of 3G/UMTS. HSDPA (High Speed Downlink Packet Access) and HSUPA (High Speed Uplink Packet Access) provide better and faster data upload and download, with even faster speeds arriving soon.

Jean L. Broge

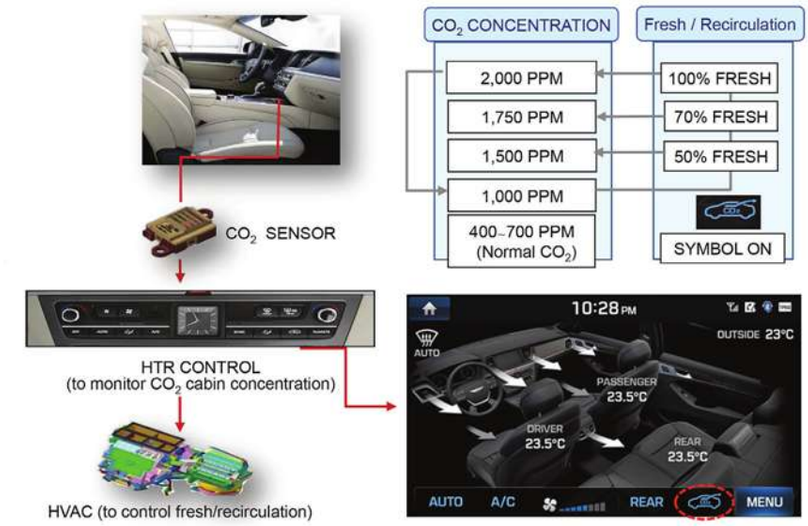
AUTOMOTIVE INTERIORS

Hyundai controls CO_2 level inside Genesis cabin

Among the many premium interior features in the 2015 **Hyundai** Genesis is a "world-first" safety technology—an in-cabin CO_2 sensor control system, located under the glove box, that combats occupant drowsiness.

When CO_2 levels reach more than 2000 parts per million (ppm)—the threshold for when occupants start to get drowsy, according to Hyundai engineers—the new ventilation system circulates freshly-ventilated ambient air. The system monitors the vehicle's intake of fresh or recirculated air using a dedicated CO_2 sensor supplied by **Halla Visteon Climate Control** Corp.

"Part of the concept of this vehicle was finding really intelligent execution of features that are desired by our customers," said Ricky Lao, Senior Manager, Product Planning at Hyundai Motor America. Or in the case of the in-cabin



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A "world-first" in-cabin CO_2 sensor control system combats occupant drowsiness inside the 2015 Hyundai Genesis.

The system monitors the vehicle's intake of fresh or recirculated air using a dedicated CO_2 sensor supplied by Halla Visteon Climate Control Corp.

CO_2 control system, a desirable feature that many customers probably were not aware of previously.

"This is an idea that came about from one of our R&D engineers," Lao explained. "He has a very long commute from the Namyang R&D Center [in South Korea] to his home, and he found that he was getting a little bit more drowsy and fatigued on his drives. What we found in our research is that there is actually a strong correlation between CO_2 levels and fatigue and alertness."

OSHA (Occupational Safety and Health Administration) standards for CO_2 levels in the office environment are 5000 ppm averaged over a 40-h work week. "With this feature, we're a little bit more aggressive," Lao noted. "At 2000-ppm CO_2 level, our system will automatically bring in fresh air to help provide a more comfortable cabin environment."

The feature can be turned off via the user settings manual, if so desired by the vehicle occupants.

System development began in 2010. For now, the technology is exclusive to Genesis, a company spokesperson said. But that could change in the future.

See http://articles.sae.org/12741 or *Automotive Engineering*'s **YouTube** video http://youtu.be/KFWRDK_2ZH8 for more on the Genesis.

Ryan Gehm

AUTOMOTIVE INTERIORS

Time-of-flight cameras detect driver's gestures, aid in autonomy

Two major design trends, the push to provide more exotic human-machine interfaces (HMIs) and the march toward autonomous driving, are sparking interest in cameras not now used in vehicles. Time-of-flight (ToF) cameras provide gesture recognition for HMIs and tell autonomous controllers whether drivers are watching the road with their hands on the wheel.

ToF cameras work much like sonar or radar, sending out a light beam and measuring how long it takes for the light to return. That lets the camera build a 3D model. Sensors are capable of understanding subtle human gestures as well as the shape, size, and behavior of objects and people inside the car. The technology is getting increased interest from automotive developers, particularly those creating HMIs.

"Comfort will be the entry point," said Gaetan Koers, **Melexis**' Product Line Manager. "If the driver's or passenger's hand moves toward the HVAC or radio control, the system will provide feedback. Gestures like turning a knob can be used to adjust the temperature or radio volume."

Melexis recently unveiled an automotive grade MLX75023 ToF sensor that's bundled with software from **SoftKinetic**, a company that specializes in 3D vision and gesture recognition solutions.

"SoftKinetic developed a library that's tuned to the automotive context, which is quite different than other consumer markets," Koers said.

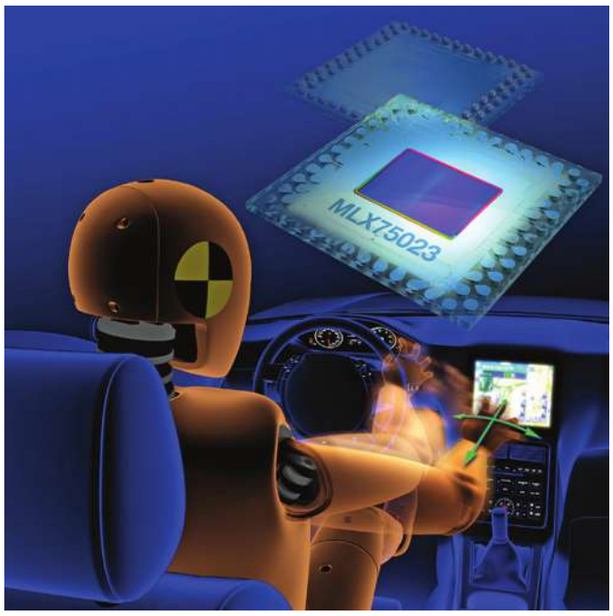
The linkup is yet another step for the merger of consumer and automotive technologies. ToF cameras for consumer applications are made by **Texas Instruments** and **STMicroelectronics**, which could easily focus on automotive uses. Along with reliability issues, usage in bright sunlight is a primary design concern for transportation cameras.

"The challenging part is to work in high levels of sunlight," Koers said. "We're at 120 kilolux, which is the amount of light you get at noontime in the Sahara."

However, that's only one of the challenges that must be met. Gesture recognition is still in its early stages. Much like voice recognition at a similar period, problems raise questions about gesture recognition's role as an automotive technology.

"The jury is still out," said Ian Riches, Global Automotive Practice Director at **Strategy Analytics**. "The second-generation Kinect sensor supplied with Microsoft's Xbox One console uses a time-of-flight camera for its range imaging, but overall impressions seemed mixed as to the usefulness and accuracy of this particular implementation. Strategy Analytics does not see ToF entering automotive until the long-term, 2020 at the earliest."

If that timetable plays out, the growing role of autonomous systems could be another driver for usage. In the initial phases of autonomous driving systems, vehicle control modules will have to determine whether the driver is distracted or actively involved in driving. Many systems are expected to activate advanced driver assistance systems more quickly when they see that the driver isn't paying attention.



Melexis and SoftKinetic have teamed up to create time of flight cameras that can detect driver gestures.

"Before the vehicle takes over something like braking, you may want to know if the driver is looking at the road or at the passenger or the radio," Koers said.

He has a more bullish outlook on ToF's adoption than Strategy Analytics' Riches.

"We expect projects to reach production next year," Koers said. "This is mostly driven by European OEMs. A lot of European carmakers feel cameras are limiting their ability to roll out more advanced ADAS systems and more advanced cockpit designs."

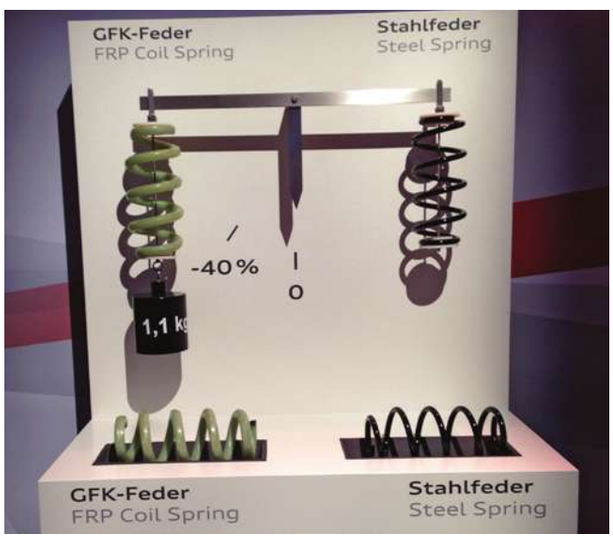
Terry Costlow

AUTOMOTIVE CHASSIS

Audi 'springs' material surprises on A6 model

Making the most of new materials to reduce weight, improve efficiency, enhance aesthetics, and achieve environmental-centric performance is the aim of every automaker. **Audi** is among those demonstrating how it can be done by determined focus on details and imaginative applications, without resorting to high-cost exotic solutions.

Audi's latest version of its A6 Avant, the 2.0-L TDI ultra (high efficiency) launched this month, is using glass-fiber-reinforced polymer (GFRP) springs to succeed conventional steel components. The A6 range is also getting an infotainment carrier that uses a continuous fiber-reinforced polyamide composite and a polyamide 6 over-molding material, to cut weight by almost 50% compared to a conventional steel solution.



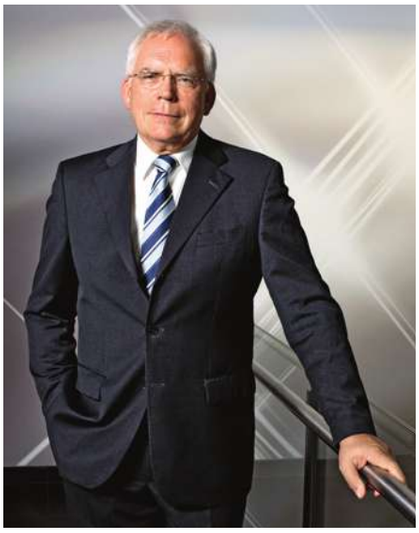
Weighing up the difference: Audi's use of weight-saving GFRP instead of steel coil springs for the latest A6 ultra.

Sporting GFRP springs

Audi's new coil springs reduce weight by some 40%. Developed in collaboration with the Italian company **Sogefi**, the coil springs are of slightly larger diameter than conventional steel. There are also fewer coils.

The springs comprise long glass fibers twisted together and impregnated with epoxy resin. Additional fibers are wrapped around the resultant core at alternating angles of plus and minus 45° to the longitudinal axis.

Audi explains that these tension and compression plies mutually support each other, and the springs can be precisely



Audi R&D boss Prof. Dr. Ulrich Hackenberg says GFRP springs on the new A6 ultra save weight, enhance comfort.

Down scaling: Audi's A6 ultra uses weight-saving GFRP instead of steel for its coil springs, and a lightweight infotainment system carrier from Lanxess.

tuned according to behavior requirements, exactly as can steel springs.

Further advantages of using GFRP include lack of corrosion. The springs, light green in color, are said to be impervious to the deleterious effect of chemicals such as wheel cleaners.

The manufacturing process demands lower energy consumption.

Audi states that typically a steel spring weighs some 2.7 kg (6.0 lb) compared to the 1.6 kg (3.5 lb) of the composite alternative. Of the total 4.4 kg (9.7 lb) saved for the A6 ultra, about half concerns unsprung weight, so there is the double bonus of weight saved and ride improved, as the suspension reacts more quickly to road surface variations.

Prof. Dr. Ulrich Hackenberg, Audi's boss of technical development, describes the springs as being "at a crucial location" in the car's chassis system: "We are, therefore, making driving more precise and enhancing vibrational comfort."

Christoph Bayerlein, Audi Development Suspension Systems Specialist, added: "The GFRP springs are very high strength, and we are confident that they can withstand stone chips that might otherwise penetrate a conventional steel spring coating and cause degradation over time. This is because the glass fibers are about 1.5 mm below the surface, so we do not expect any issue of fatigue behavior to adversely affect the composite springs if there is some surface damage."

The frugal A6 Avant ultra was chosen to be the first model to use the lightweight GFRP springs as it would clearly demonstrate how the weight saving they brought could make a tangible difference, said Bayerlein: "Furthermore, we wanted to choose a model in the A6 range with a volume that also fits with the volume the supplier can deliver in this current phase. For the future, we want to increase our usage of composite springs."

At present, 34 million steel springs are produced per year for use by Audi vehicles. Said Bayerlein: "Although the composite springs are initially a very small project for us, it is something we are very interested in applying to future models. In particular, there are no limitations with the springs; a crucial part of the original design brief was that they could be used on both front and rear strut configurations and are suitable for all future Audi projects."

Audi's "ultra" designation for some of its models describes particular focus on the latest technological advances spanning lightweight construction to engine development.

The venture is a joint one between Audi and **Allevard Rejna**, part of the Sogefi Group, which spends almost 3% of its total revenues on R&D. Sogefi states that the patented new coil spring can show a weight saving of up to 70% of that of a comparable steel spring. The GFRP springs have been designed to be assembled on cars and light commercial vehicles without affecting the suspension system architecture for a weight reduction of 4 to 6 kg (8.8 to 13.2 lb) per vehicle (depending on coil spring design and vehicle type) and a significant reduction of unsprung mass.

CO_2 is also reduced during the production process of the GFRP springs compared to steel.

Sogefi CEO Guglielmo Fiocchi said: "Innovation in the car sector, starting from reducing weight and improving the efficiency of vehicles, now depends significantly on components companies."

A6 composite carrier

The A6's weight-saving infotainment system carrier holds an amplifier and optional TV tuner. It is fabricated with Tepex and Durethan from supplier **Lanxess** to deliver required high stiffness and fatigue resistance levels.

Lanxess's Lightweight Design Specialist, Martin Klocke, said: "This application underlines the enormous weight-saving potential of hybrid technology and continuous fiber-reinforced polyamide composite for lightweight design of structural components. We are confident that this hybrid design also is suitable for other components in motor vehicles, such as carriers for pre-installed electric and electronic modules."

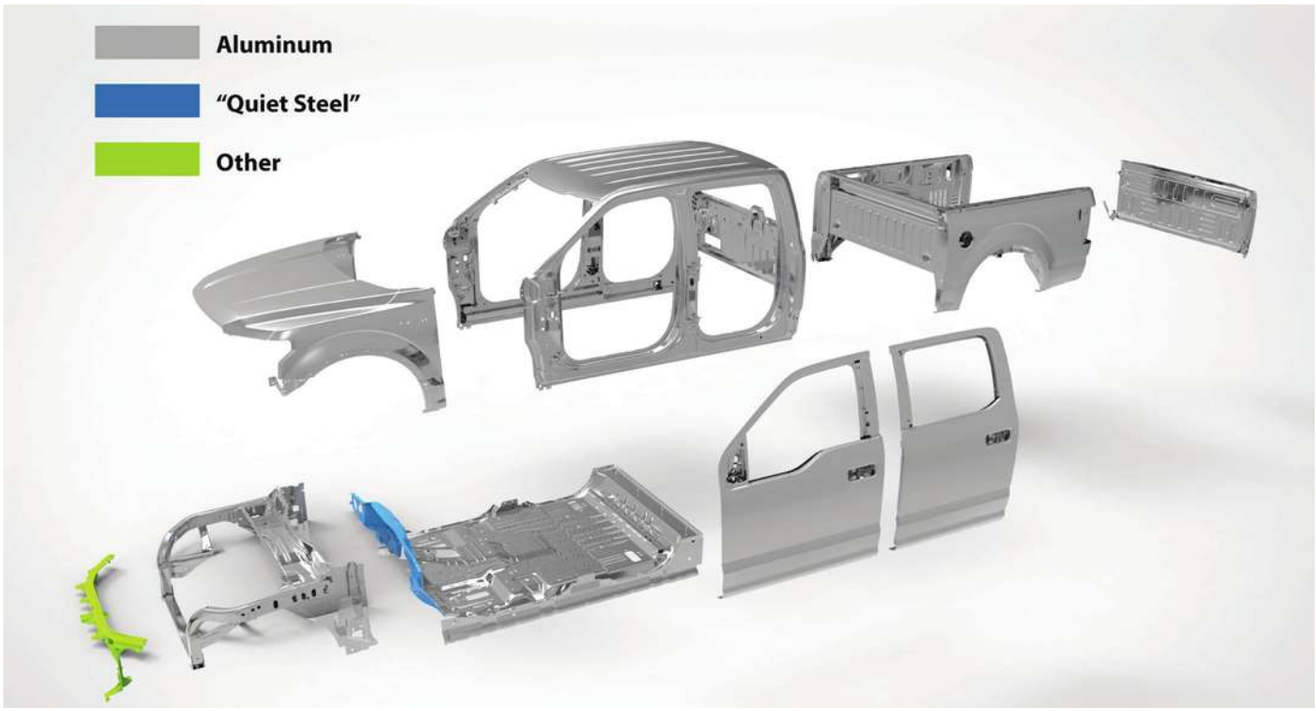
Lanxess created the solution together with Audi's Control Device Package Development and Fiber-Reinforced Plastic Technology departments. Other companies involved included **KraussMaffei**.

For the prototype system, KraussMaffei developed a fully automated manufacturing cell with a bespoke adjusted handling system and a heating unit placed directly above the mold platen. Using this as a basis, **Reinert Kunstofftechnik** created an optimized manufacturing cell for fully automated series production of the carrier.

Stuart Birch

AUTOMOTIVE BODY

2015 F-150 aluminum body creates challenge for auto body shops



The 2015 Ford F-150 clearly requires specialized training. It is spot-welded in only two areas; the remainder of the attachments are made with structural adhesives and specially coated self-piercing rivets.

Aluminum panels for automotive application are nothing new. They've been used for hoods and decklids for many years, particularly when an automaker needed to shave a few pounds to fit a vehicle into a particular emissions class. And a number of luxury cars have had some models with bodies almost entirely of aluminum, such as **Jaguar**, **Range Rover**, **Aston Martin**, **Audi**, **Porsche**, and now **Tesla**. But **Ford**'s 2015 F-150, the best-selling vehicle in the U.S., with its all-aluminum body, is raising the issue of body repair to a level that can challenge America's mainstream auto body repair shops.

The F-150 retains a steel frame to go with its aluminum panels, but the amount of aluminum and the associated technology that enabled it will require new tools and techniques for the body shop. Wait, what about the aluminum body luxury cars? How have they been repaired?

The answer is that the premium car makers with all-aluminum models have been very selective. They've approved only "cream of the crop" shops that could afford the special equipment necessary. Because they were considered "craft shops," they could charge much higher rates. With just a handful of competitors in a large geographic area, they had enough volume to justify the necessary investments in equipment and technician training.

Servicing 40 Teslas a month

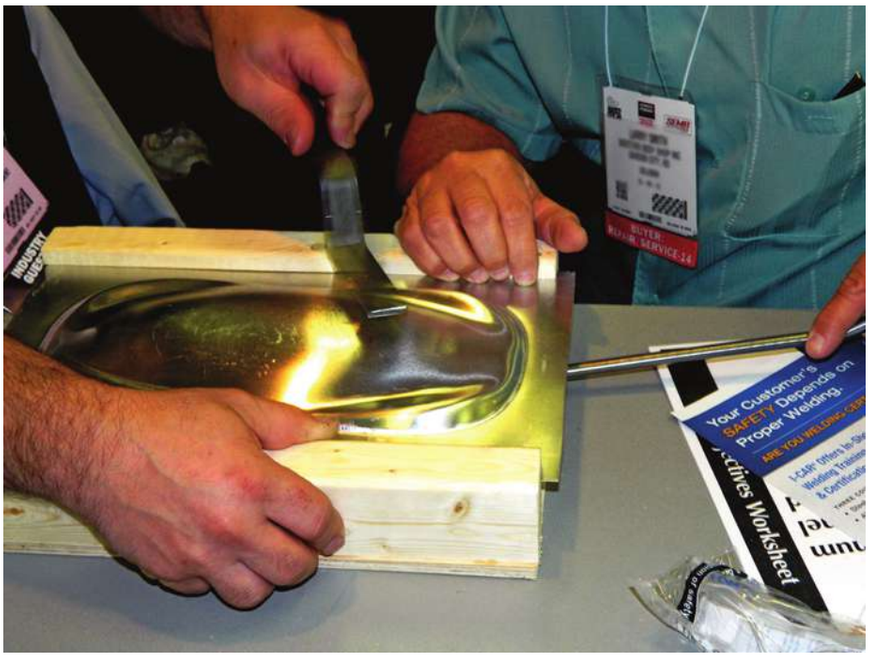
Kye Yeung is executive committee secretary of the **Society of Collision Repair Specialists** (SCRS), a trade association of body shops that exhibited at the recent **SEMA** Show (Specialty Equipment Market Association). He operates a recommended facility for Tesla, Aston Martin, Range Rover, and Jaguar, and told *Automotive Engineering* he has an investment of approximately $2 million in his shop. He said he pays premium wages to his employees and is able to command up to three times the labor rate of other body shops.

Yeung's operation, based in the southern part of Orange County, CA, with only one comparably approved competitor in a wide area, typically services 40 or more Teslas a month. He estimates that there are more than 7000 Tesla vehicles on the road in his market area. Yeung said his shop has a six-week backlog and is able to refuse to deal with insurance companies. He employs 14 technicians, five of whom (including himself) are certified to do structural repairs for all of the makes in which his shop is specializing.

The designated body shops are the only ones that can buy OE structural replacement parts for these high-end aluminum vehicles, Yeung said, which helps direct the customer traffic. Cosmetic parts are not under such restrictions, but in practical terms an owner would not know what was needed in most cases, and the training-and-special-tools factor is powerful.

The investment in F-150 aluminum body service is reportedly far lower than for the premium cars. Yeung estimated the amount would be in a range of $50,000-$70,000 and, he added, a shop would have to pay an annual fee for an independent agency to inspect and certify that it continues to meet Ford standards. Despite the lower overall cost,

This Tesla chassis is all aluminum, and structural repair parts are restricted to approved shops. It was on display at the SEMA Show by SCRS.



Technicians in an I-CAR class on aluminum-panel dent removal found that the work requires a learning curve.

Yeung said he has no intention of servicing the new F-150, describing the service system as a "free for all" in comparison with the "craft"-oriented league in which his shop plays.

The 2015 F-150, however, clearly requires specialized training. It is spot-welded in only two areas, where the pickup bed floor attaches to crossmembers, as the welds have lower strength than the aluminum pieces that were joined. The remainder of the attachments are made with structural adhesives and specially coated self-piercing rivets. And where aluminum is joined to steel but the metals cannot be isolated with adhesive or coatings to prevent corrosion, plastic bushings are used.

Dent removal techniques

Knocking out aluminum dents, even where there is access, is an acquired technique. *Automotive Engineering* watched a room full of experienced auto body technicians in a SEMA Show I-CAR (**Inter-Industry Conference on Collision Auto Repair**) class try to remove the same test crease in an aluminum panel with hand tools. They clearly were at the very beginning of a learning curve.

Where an F-150 panel is dented but there is access just to the exterior side, the shop also can weld on aluminum pulling studs to pull it out. However, care must be exercised in the placement of grounding clamps, because of the electrical conductivity of aluminum. This was just one of the special cautions noted by David Solmes, instructor in aluminum body panel repair. He spoke at a training session by I-CAR, which is a nonprofit training organization. It was one of several such sessions at the recent SEMA tradeshow.

Solmes also cautioned that although aluminum panel dents may be removed by shrinking the metal with heat, the technician has to be careful to stay below the 425°F (218°C) limit of the typical alloy. When the temperature applied is too high, he said, the aluminum is annealed and loses strength.

"At 570°F [almost 300°C]," he added, "a Ford F-150 panel becomes aluminum foil."

Even where the heat can be useful, he noted, the technician has to keep it away from structural adhesive, which typically softens at 400°F (204°C). To avoid this issue, the technician should take a protective step. One would be to position a wet rag close to the joint. Some technicians apply thermal paint or crayon, which melts and runs when the threshold temperature is reached.

Infrared thermometers also can be used, but as Solmes pointed out, a reflective aluminum panel surface will produce a significantly incorrect reading. A strip of nonreflective tape should be applied to the panel to provide a suitable target for the infrared beam. By contrast, low-carbon steel does not anneal until about 1650°F (almost 900°C).

Paul Weissler

AEROSPACE MATERIALS

Aerojet Rocketdyne pursues copper alloy additive manufacturing for thrust chamber assembly

NASA and **Aerojet Rocketdyne**, a Sacramento, CA-based **GenCorp** company, announced Oct. 17 that they successfully completed a series of hot-fire tests on an advanced rocket-engine thrust chamber assembly (TCA) using copper alloy additive manufacturing (AM) technology.

The testing, claimed to be an industry first, was conducted with cooperation between Aerojet Rocketdyne, NASA's Space Technology Mission Directorate Game-Changing Development Program, and NASA's **Glenn Research Center** under a Space Act Agreement.

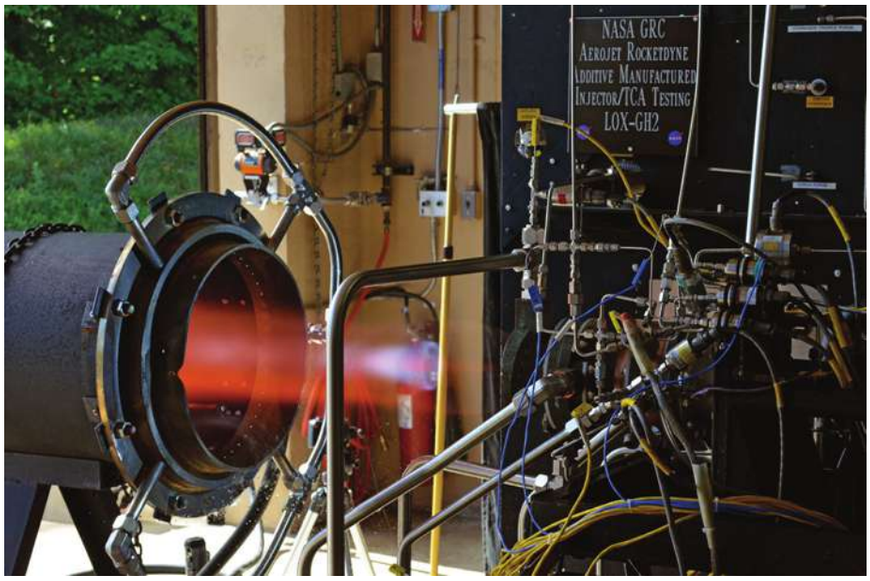
The hot-fire tests used Aerojet Rocketdyne's proprietary Selective Laser Melting (SLM) copper alloy enhanced heat transfer design chamber, which demonstrated a "significant increase in performance" compared to traditional combustion chamber designs and material systems.

"In all, NASA and Aerojet Rocketdyne conducted 19 hot-fire tests on four injector and TCA configurations, exploring various mixture ratios and injector operability points. At the conclusion of the tests, the injector and chamber hardware were found to be in excellent condition, and test data correlated with performance predictions," Lee Ryberg, Lead Project Engineer on Aerojet Rocketdyne's Additive Manufacturing development team, said in a statement announcing the successful testing.

Aerojet Rocketdyne told *Aerospace Engineering* that it has been "aggressively working the methodical development of AM" for several years, for a number of alloys. The specific copper alloy employed in this round of hot-fire tests is proprietary and has been in some phase of development and demonstration for about the past three years.

"SLM of copper can be pretty tricky, for the reasons…regarding the conductivity of Cu," a company spokesperson shared. "So it can be a challenge to get a solid, well-managed microstructure that will result in good mechanical properties."

Other materials the company is exploring for the AM technology include a few different nickel alloys, some titanium, a couple of steels, and some aluminum, the spokesperson said.



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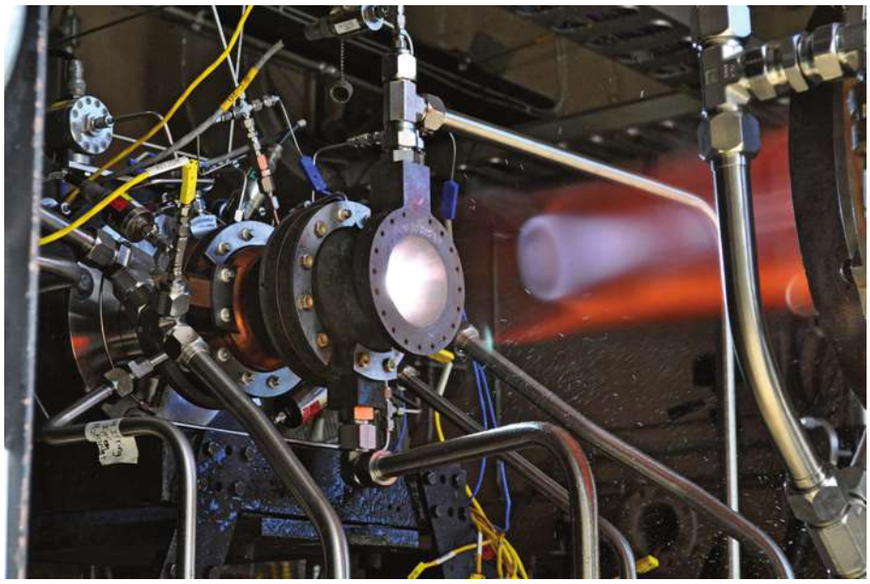


At the conclusion of the tests, the injector and chamber hardware were found to be in excellent condition, and test data correlated with performance predictions.

"This work represents another major milestone in the integrated development and certification of the materials characterization, manufacturing processes, analysis, and design-tool technologies that are required to successfully implement Selective Laser Melting for critical rocket engine components," Jay Littles, Director of Advanced Launch Programs at Aerojet Rocketdyne, said in the statement. "Aerojet Rocketdyne continues to expand the development of novel material and design solutions made possible through additive manufacturing, which

will result in more efficient engines at lower costs. We are working on a range of additive-manufacturing implementation paths—from affordability and performance enhancement to legacy products such as the RL10 upper stage engine. We also are applying the technology to next-generation propulsion systems, including the Bantam Engine family, as well as our new large, high-performance booster engine, the AR1."

The traditional materials that could be replaced by SLM copper alloy technology depend on the specific application. "For some of our legacy products, this type of additively-manufactured copper combustion chamber could replace a brazed steel tube combustion chamber. Moving from brazed steel tube construction to an integral copper chamber would have benefits in terms of component cost, lead time, and even performance, depending on the configuration," the spokesperson told *Aerospace Engineering*.

Performance improvements, for this application, can include improved thermal management within the combustion chamber, "which can relate to improved component durability and even combustion efficiency," according to Aerojet Rocketdyne.

Full-scale demonstration is the next step in the technology's development path.

Ryan Gehm

AUTOMOTIVE MATERIALS

Growing interest in bio-based material parts

Plastic composite parts outnumber bio-based material vehicle applications, but "green" projects are making inroads by overcoming various hurdles.

"The primary challenges to using bio-based materials, as with any new materials, are meeting or exceeding the cost targets and the performance characteristics of the incumbent material," Valerie Sathe Brugeman, Senior Research Project Manager in the Sustainability and Economic Development Strategies Group at the **Center for Automotive Research** (CAR), noted in an interview with *Automotive Engineering*.

Brugeman moderated the "Bio-Based Materials: Ready For Mainstream?" panel discussion on December 4 at Schoolcraft College's VisTaTech Center in Livonia, MI. It was CAR's first event on the bio-based material topic, underscoring the auto industry's interest in making vehicle parts from sustainable materials.

Prior to the Great Recession of 2008-2009, **RheTech** Inc. executives had a strong motivator for diversifying the privately held firm's portfolio. "We felt that we had to get into the bio-renewable segment because non-renewable materials aren't going to be around forever," said James Preston, RheTech's Vice President of Strategic Growth.

RheTech's RheVision natural fiber families include coconut fiber, flax fiber, wood fiber, and rice hulls (shown).

The Whitmore Lake, MI-based company, a provider of filled and reinforced polypropylenes, engineered resins, color concentrates, and additives, spotlights sustainable materials via its RheVision portfolio of bio-fiber-reinforced thermoplastics.

"The majority of our bio-fibers are true waste products. They are not grown for us, nor do they take away from food production," Preston said.

Certain natural fibers (ground rice hulls, ground wood fiber, and flax fiber) match up very well to the properties of traditional ground-mineral-reinforced polypropylenes. However, natural fibers fall short in tensile strength compared to glass-fiber-reinforced polypropylenes.

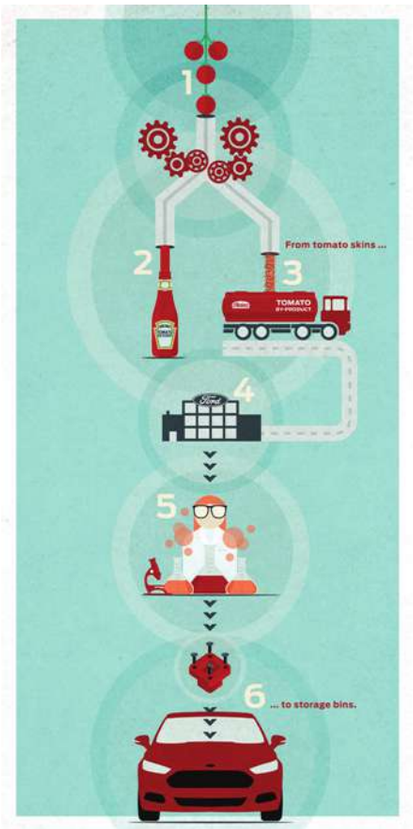
"We've done a great deal of work with **Dow Corning** on an additive that could increase the tensile strength of these natural-fiber materials. We're completing our commercial trials and should have the results in the second quarter of 2015," said Preston.

Physical Property Tests	10% Glass Fiber Reinforced Polypropylene	20% Flax Fiber Reinforced Polypropylene
Filler Percentage	10	20
Density	0.98	0.97
Tensile Strength (PSI)	7,800	5000
Flexural Modulus (PSI)	356,000	365,000
Notched Izod (ft-lb/in)	0.9	0.5
Heat Deflection @ 66 PSI (F)	300	290
Heat Deflection @ 264 PSI (F)	258	200
Mold Shrinkage	0.005	0.005

Comparative data on flax-fiber-reinforced polypropylene vs. glass-fiber-reinforced polypropylene is depicted via a RheTech-provided chart.

Focus on interiors

Plastic composite material parts are a vehicle interior mainstay, but the door is open for bio-based materials usage. Rose Ryntz, PhD, Senior Director of Advanced Engineering and Material Development, North America for **International Automotive Components**



Ford researchers are evaluating dried tomato skins as a bio-based material.

A Ford Fusion Energi plug-in hybrid research vehicle's interior fabric, containing up to 30% plant-based material, is made from The Coca-Cola Company's PlantBottle Technology (trademarked). The car's PlantTechnology is used for seating upholstery, door panel inserts, headliner, and carpet mats. The renewable-fabric research car debuted at the 2013 Los Angeles Auto Show.

(IAC), pointed out that "virtually every interior component can be made of bio-content material."

IAC's interior portfolio includes parts made from bio-based materials, such as the natural-fiber-based door bolster used on the current **Ford** Escape utility vehicle.

"We're about to test prototype parts made with carbon fiber and the natural fiber, kenaf," said Ryntz. A door bolster made of carbon fiber and kenaf is expected to provide a 35% to 50% weight savings in a production application. "IAC produces compression molded parts made from natural fibers that are 3 mm thick, but those parts could drop to 1.5 mm to 2 mm in thickness because of the stiffness provided by the carbon fiber," Ryntz said.

Carbon-fiber/natural-fiber door bolsters are planned as a cost-neutral counterpart to natural-fiber door bolsters.

Henning Karbstein, **BASF** Corp.'s Manager of New Business & Idea Management for Dispersions & Formulation Additives in North America, said that the North American market typically expects a short-term return on investment without a performance compromise from a natural-fiber composite solution. Paying a "premium for a green solution is mostly not accepted," said Karbstein.

Ford collaboration pursues tomato-based composites

A Ford team is looking for green material solutions, a task that matches the sentiments of auto pioneer Henry Ford. "He had a vision that the farmer and the automaker each produced what the other needed," said Ellen Lee, PhD, Team Leader of Plastics Research at Ford Motor Co.

The team's key research areas are bio-based and sustainable foam development, natural fibers for reinforcement of composite materials, bio-based resins, and recycled materials. Their R&D work is being enhanced by a unique industry-to-industry partnership, the Plant PET Technology Collaborative (PTC).

Ford, The **Coca-Cola** Co., H.J. **Heinz** Co., **Nike** Inc., and **Procter & Gamble** formed the PTC strategic working group in June 2012. "We're sharing a lot of information that doesn't really affect our competitive advantage," said Lee, noting that various production processes are being evaluated from lifecycle assessment and other perspectives.

One notable outgrowth from the collaboration deals with finding a viable automotive application for a tomato processing byproduct.

"Heinz processes millions of tons of tomatoes every year to make their ketchup products. Some of the leftover tomato pomace goes into pet food, but for the most part there is not a big value-add use for the pomace; it's a waste product," Lee told *Automotive Engineering*.

Ford researchers have been mixing the pomace with plastic resins to make composites. Explained Lee, "Because we have many different types of composites that need to meet different requirements and functions, we think we can find an area to use it. We're still in the materials development phase, but we're starting to reach out to the supply base, looking for compounders that can help develop formulations for the materials."

The ability to use tomato pomace as a feedstock for making storage bins, wiring brackets, or other automotive components looks promising, but there are challenges.

"One of the hurdles is cost. Even though it's a waste product, there is a cost if you have to dry the tomato skins.

IAC produces the natural-fiber door bolster (shown) for 2015MY Ford Escape. The Tier 1 supplier makes various automotive components from composite and natural materials, including soy, wheat husk, straw, and sisal.

And if you have to transport the pomace, that adds cost," Lee said.

Sustainable supply chain

Growing renewable resources near the supply base is a transportation cost saver, but there are many factors affecting the sustainable materials supply chain, noted RheTech's Preston.

"A lot of companies may not be able to find some of the vendors we did," said Preston. "We're working with the largest walnut producer in the United States, and about two and a half years ago they set up an operation to grind the shells."

RheTech uses the walnut shells as reinforcement for certain polypropylene compounds.

IAC's Ryntz agrees that access to crops and other bio-based resources is one of several stepping stones toward vehicle implementation.

"The big thing when you're talking natural products is where do you get them? But just as important is the growing season, the sorting process, and the type of ancillary processes that are needed to assure the quality control specifications," said Ryntz.

Preston expects bio-based consumer goods to grow at a faster rate than automotive uses over the next 10 years.

"Automotive OEMs and Tier 1s are definitely looking at bio-based material applications; some are more purposeful than others. Ford and **Hyundai**, for example, have very aggressive programs to get natural fibers in place," said Preston. "We believe it's just a matter of time before more companies jump on the bandwagon as automakers understand the capabilities of natural fibers."

Kami Buchholz

MATERIALS

Toho Tenax develops 'super-heat-resistant' prepreg for engine apps

Toho Tenax Co., Ltd. announced late last year that it had developed a new prepreg—a carbon-fiber sheet pre-impregnated with matrix resin—that offers super-high-heat and -oxidation resistance suited to aircraft and automotive engine compartments.

The new bismaleimide resin-impregnated prepreg does not reach glass-transition below 320°C (608°F), the result of Toho Tenax's original resin-formulation technology. Transition temperatures around 200°C (392°F) are typical of other prepegs, according to a company spokesperson. The supplier declined to provide any more details on the resin composition and its development program due to non-disclosure agreements (NDAs).

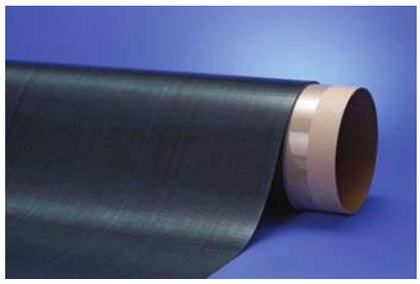
The new prepeg also maintains oxidation resistance without heat cracks under continuous use in the upper 200°C (lower to mid 500°F) range. This capability is what makes the technology unique, the spokesperson said.

Conventional bismaleimide resin-impregnated prepreg already has been used for high-temperature applications such as automotive and motorbike engine compartments, but it has experienced degradation, according to Toho Tenax, due to resin oxidation after continuous use at high temperatures. For example, microcracks can form after repeated heat expansion and contraction.

The super-heat-resistant prepeg cures at 180°C (360°F) for 2 h in the mold, then at 210°C (410°F)/9 h, 250°C (480°F)/10 h, and 270°C (520°F)/10 h without the mold for post-cure. The production volume/limit for this new prepeg has not been fixed, the spokesperson said.

Production applications are currently in progress in the aerospace industry, but again details could not be provided due to NDAs with clients.

Aerospace has been a traditional focus area for Toho Tenax, but the Japanese materials supplier is now expanding the scope of its technology development to include other high-heat applications such as ground vehicles. For example, the company has announced another prepeg development—this one initially targeted for automotive applications and focused on rapid curing for increased productivity.



Toho Tenax's new bismaleimide resin-impregnated prepreg does not reach glass-transition below 320°C (610°F). Production applications are currently in progress in the aerospace industry.

The new prepreg, which is said to feature excellent surface texture and formability, cures in 3 min at 150°C (300°F) and minimizes resin being expelled from the prepreg due to molding pressure. The result is an increase in production efficiency "by a factor of many dozens," according to Toho Tenax, which will allow the company to raise annual production capacity to 50,000 carbon-fiber-reinforced plastic (CFRP) sets.

Toho Tenax plans to explore opportunities for aircraft and other fields, including sports equipment, with this new prepeg due to its formability at low pressure of around 0.5 MPa (70 psi). A flame-resistant feature now under development is expected to further expand applications to consumer electronics and other general applications.

The materials supplier also intends to develop CFRP technologies for structural parts. "Material development for first and second structural members of aircrafts and frame of automobiles are in progress," the spokesperson shared.

Toho Tenax is the core company of the **Teijin Group**'s carbon fibers and composites business.

Ryan Gehm

AEROSPACE SIMULATION

NVision aids aircraft repair station in quickly obtaining FAA approval

A certified **FAA** repair station recently used a 3-D laser scanning system to document its work on a passenger jet part such that the station was able to obtain the necessary FAA approval for the repair in much less time than usual.

Due to the stress and strain of normal usage, the aircraft component—part of a key system—eventually requires repair after a certain number of hours. By law, the FAA must approve any modification or repair made to an aircraft component to ensure it doesn't degrade the structural integrity of the part, which could impair its performance and jeopardize the safety of passengers and crew.

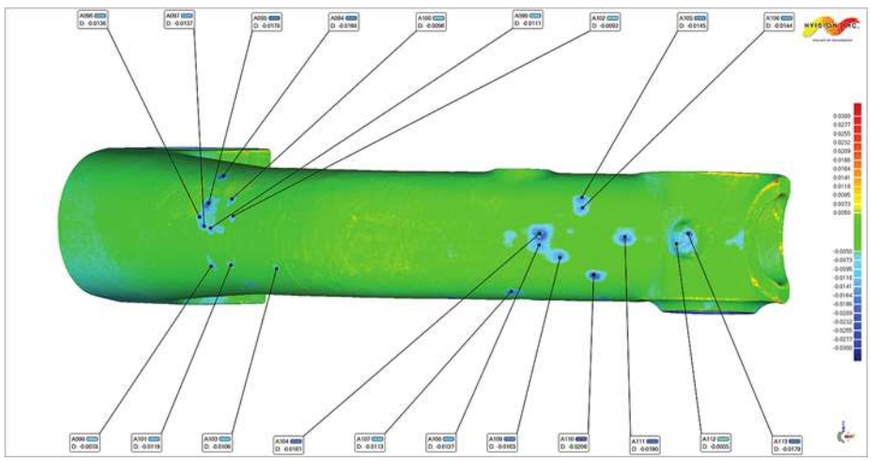
The station, which specializes in the repair and overhaul of aerospace components and systems, needed to first remove corrosion from the part to make necessary repairs prior to reassembling the system. However, prior to starting the repairs, they were cognizant of the need to submit a report for FAA approval showing exactly how much metal was removed in the corroded areas. Verifiable accuracy was paramount to the process.

The station brought the part to **NVision**, with 25-years experience in 3-D laser scanning and reverse engineering, so NVision engineers could 3-D map its exact geometry both before and after the corrosion was removed.

NVision has a wide range of 3-D scanning systems available for aviation work, with ultra-high accuracies starting as precise as 0.0002 in. For this project they utilized the HandHeld 3-D laser scanner, which is very accurate and capable of capturing 60,000 separate measurements per second. The HandHeld Scanner is highly versatile and quickly obtains dimensions from objects of almost any size or shape.

Using the HandHeld Scanner, it took NVision technicians about half a day to scan the part before corrosion was removed and another half day to scan it after the removal of the defects. NVision then created an inspection report, with color deviation chart, precisely documenting the exact amount and location of any corrosion and associated metal that had been removed from the part.

Actual part after removal of corrosion. The shiny areas where it was sanded are clearly visible.



The color deviation shown in this Aviation Inspection Report depicts the variation between the scan of the corrosion vs. the scan of the sanded part.

The report was reviewed and approved by the FAA.

In another application, the repair station had to urgently repair a faulty bracket on a **Boeing** 737, which had created an aircraft-on-ground, or AOG, situation.

An AOG arises when a problem—for example, a worn, defective, or missing part—is serious enough to prohibit an aircraft from flying. Due to the time, expense, and inconvenience involved in grounding an aircraft, resolving an AOG quickly is a top priority.

The repair station needed to make a new bracket as soon as possible. The station technician delivered the bracket to NVision at 1 p.m. and was able to return the next morning at 10 a.m. to receive a completed 3-D CAD model of the part. This 3-D model was imported into a CAM system to generate a milling path. A replacement bracket was quickly made on a CNC machine and installed, allowing the 737 to fly again.

Jean L. Broge

AEROSPACE SIMULATION

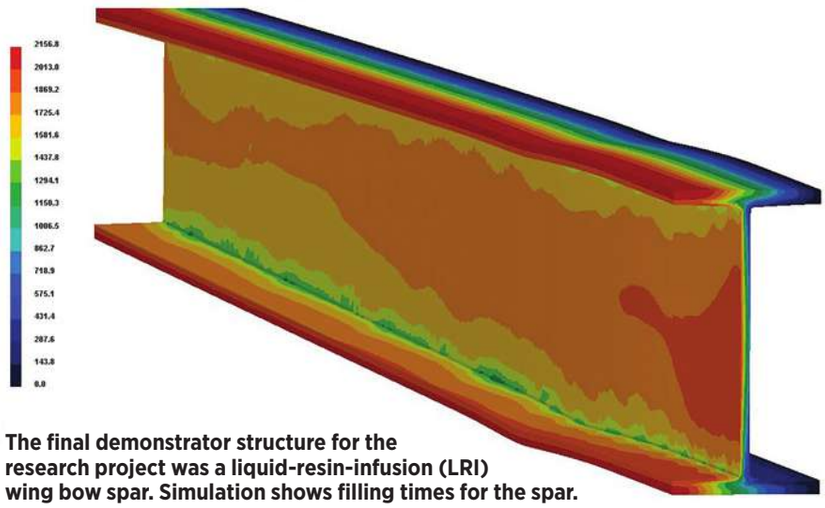
Infusing lightweight composite structures

Liquid resin infusion (LRI) is a proven manufacturing technology for both small- and large-scale structures for which, in most cases, experience and limited prototype experimentation is sufficient to get a satisfactory design. However, large-scale aerospace and other vehicle structures require reproducible, high-quality, defect-free parts with excellent mechanical performance. These requirements necessitate precise control and knowledge of the preforming (draping and manufacture of the composite fabric preforms), their assembly, and the resin infusion.

The INFUCOMP project is a multi-disciplinary research project to develop necessary CAE tools for all stages of the LRI manufacturing process. An ambitious set of developments has been undertaken that build on existing capabilities of leading drape and infusion simulation codes available today. The main objective of the European Research Consortium is to develop liquid composites molding (LCM) for the aeronautic sector.

Currently the codes are only accurate for simple drape problems and infusion analysis of resin transfer molding (RTM) parts using matched metal molds. Furthermore, full chaining of the CAE solution will allow results from materials modeling, drape, assembly, infusion, and final part mechanical performance to be used in subsequent analyses.

Although the materials and manufacturing methods in INFUCOMP are specific to aerospace structures, the research work is expected to be of great value to other industries, including automotive and manufacturing, energy, rail, and marine.



The final demonstrator structure for the research project was a liquid-resin-infusion (LRI) wing bow spar. Simulation shows filling times for the spar.

Researchers first performed validations on simplified components, one being this "Ω stringer" final part.

INFUCOMP has built on PAM-RTM, an existing simulation software from **ESI Group**, to provide a full solution chain for LRI composites, including fabric modeling, drape, assembly, infusion, cost, and final part performance prediction. Simulation tools will avoid costly and time-consuming prototype testing, allow the CAE design of alternative manufacturing routes, and enable cost-effective, efficient LRI composite structures to be designed and manufactured.

During the industrial validation phase of the project on simplified components and a relevant LRI aircraft substructure, researchers from ESI Group, **Daher Aerospace**, **University of Stuttgart**, and **INASCO** (Integrated Aerospace Sciences Corp.) employed numerous enhancements to the state-of-the-art for resin infusion simulation—in particular, better viscosity models and essential developments to run under distributed memory processing (DMP) to take advantage of new-generation cluster computers and massive parallel computing. This includes coupling of modeling and monitoring, allowing a combination of predictive capabilities provided by simulation with the capability of detecting unexpected events and variations in real time provided by process monitoring.

Experiment setup

For the project, researchers employed the DiAMon Flow monitoring system developed by INASCO, which combines flow, thermal, and cure monitoring as part of an integrated sensor comprising electric contact pairs, an inter-digitized micro capacitor, and a thermocouple. Capabilities include measurement of the in-plane position and speed of the flow front, estimation of the degree of cure (through material state models that result from the correlation between the dielectric measurements and available cure kinetics models), and continuous monitoring of temperature.

All the sensors used in the system are resistance sensors: When the resin arrives on the sensor, a 10 V dc passes from one of the pins through the resin and into the other pin. From the voltage drop that is recorded by the "high resistance sensing electronics," the presence of resin on this location, the value of the resin resistance, the arrival time of the resin, and the time since the resin arrival are noted. The sensing area of each individual sensor is protected from direct contact with the carbon fabrics to prevent the sensor from short-circuiting. This protection uses two layers of glass cloth positioned on top of the sensing area.

The resin used in this project is RTM6 from **Hexcel**. The preforms used are made of Hexcel twill fabric 48302

weaved with carbon fibers T700 12K.

Material data were taken from previously conducted experimental and modeling work:

- Resin viscosity: 0.033 Pa.s-1 (taken from RTM6 manual Hexcel); also, a new constitutive model has been applied
- Distribution medium permeability (measured by University of Stuttgart): K=0.74E-10 m^2
- Preform (48302 T700 Hexcel reinforcements) having in-plane permeabilities K1=K2=4.48E-12 m^2 and through thickness permeability K3=2.79E-14 m^2.

The distribution medium is a two-dimensional flowing aid used to ease resin flow and distribute the resin across the surface of the laminate. It is commonly accepted to consider K1=K2=K3 for distribution media.

Validations on simplified components

Validations on small-scale singularities that are representative of industrial issues were conducted. For singularity #1, "step," the part to be infused has two preforms: a lower preform of 3 mm (0.12 in) thick and a thicker upper preform of 4.2 mm (0.165 in). The sensors were positioned, and simulations were carried out with PAM-RTM 2013. A 549,000 tetrahedron mesh was generated with Visual-Mesh. This mesh was split into two zones, with one zone for the distribution medium and one zone for the preform. Distribution medium permeability tensor was taken: K1 = K2 = K3 = 2E-10 m^2 (calibrated to match with experiment).

Simulation results show that resin flows preferentially into the distribution medium; however, the preform starts to be impregnated before the complete filling of the distribution medium, resulting in an orthotropic flow process.

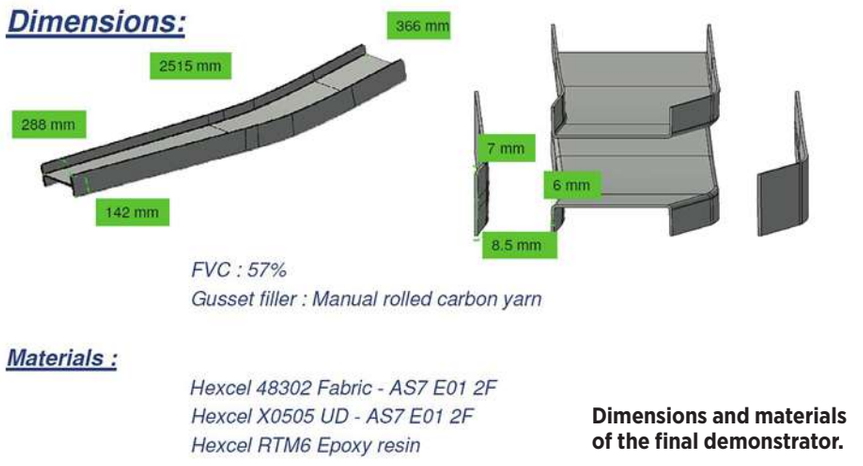
Experimental measurements give a filling time of approximately 900 s (15 min). The distribution medium permeability tensor used in simulation has been calibrated to match with the experiment result. This flow media permeability tensor will then be used for all other cases to validate the simulation tool.

For singularity #2, "Ω stringer," the manufacturing part is made with a simple preform that is 3 mm thick, 280 mm (11.0 in) wide, 380 mm (15.0 in) long, and reinforced by a Ω stringer that is 3 mm thick and 93 mm (3.7 in) wide. Sensors were positioned, and a 79,600 tetrahedron mesh was generated with Visual-Mesh. The mesh was split into three zones, and material data were taken:

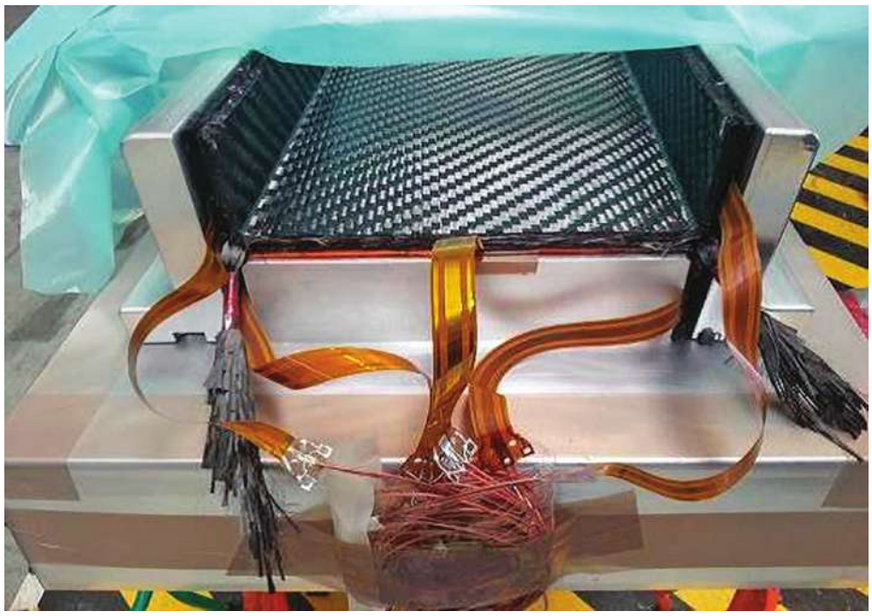
- Resin viscosity: 0.033 Pa.s-1 (taken from RTM6 manual Hexcel)
- Distribution medium permeability: K1=K2=K3 = 2E-10 m^2 (calibrated for the step case)
- Preform (48302 T700 Hexcel reinforcements) permeability (measured by Hexcel reinforcement):
  - K1=K2=4.48E-12 m^2 in the plate and in the Ω
  - K3=2.35E-14 m^2 in the plate (vf = 58%) and K3=1.974E-14 m^2 in the Ω (vf = 61%).

Experimentally, resin passed through the vent at 24 min (1440 s) after the start of infusion. The vent was clamped at 45 min (2700 s) after beginning of infusion. According to monitoring results, the resin maintained progress after clamping and triggered the sensors at 60 min (3600 s).

The simulation results show a resin arrival at vent location after 1447 s and a total filling time of 3656 s. These results are extremely close to the experimental results.



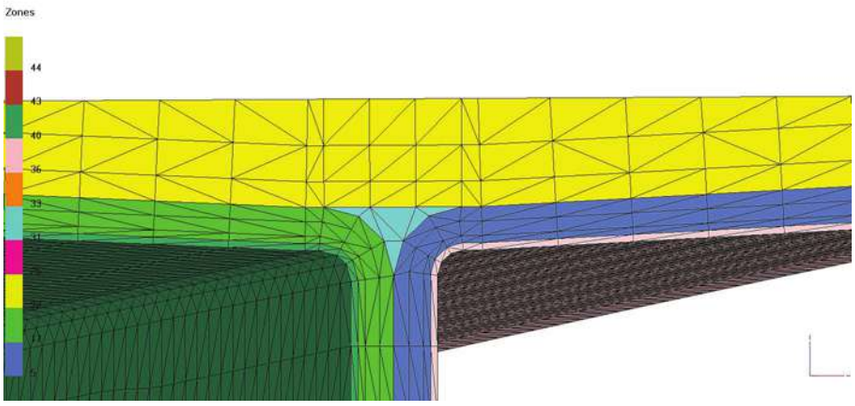
Dimensions and materials of the final demonstrator.



Experimental set-up for the wing bow spar final demonstrator.

Industrial demonstrator

The final demonstrator is a generic wing bow spar—an industrially relevant LRI aircraft substructure. Distribution media has been located on both sides of the



Mesh T-junction zone for final demonstrator structure. The yellow zone represents the upper plate, the thin layers in dark green and light rose will be used for the distribution media whereas the dark blue and green zones represent the C frames. In the middle of the image, the blue set of elements represents the "nailhead."

part based on simulation results to optimize through thickness flow and filling time. The final demonstrator was equipped with several DiAMon Flow sensors to compare experimental results with simulation results.

A 950,424 tetrahedron mesh was generated with ESI's Visual-Mesh software. Four zones (group of elements) were generated to define materials properties. One for the two distribution media, one for the gusset filler, one for the two "C" frames forming the "I" stringer, and one for the top and bottom plates.

The preform is made of the woven fabric type 48302E01 and the unidirectional fabric type X505E01 provided by Hexcel reinforcements, and permeabilities of those two reinforcements were measured by Hexcel reinforcements.

- 48302E01: K1 = 9.76E-12 m^2; K2 = 9.76E-12 m^2; and K3 = 1.13E-11*exp(-9.8 vf) m^2 (vf = fiber volume fraction)
- X505E01: K1 = 2.03E-12 m^2; K2 = 2.03E-12 m^2; and K3 = 1.11E-12*exp(-9.82 vf) m^2.

The bottom and the upper plates are made of both 48302E01 and X505E01. To represent properly the preform permeabilities, an equivalent permeability was computed for the whole stacking. The "C" frames constituting the "I" stringer are made only with the 48302E01 reinforcement at 57% of fibers.

Permeabilities used in the simulation are:

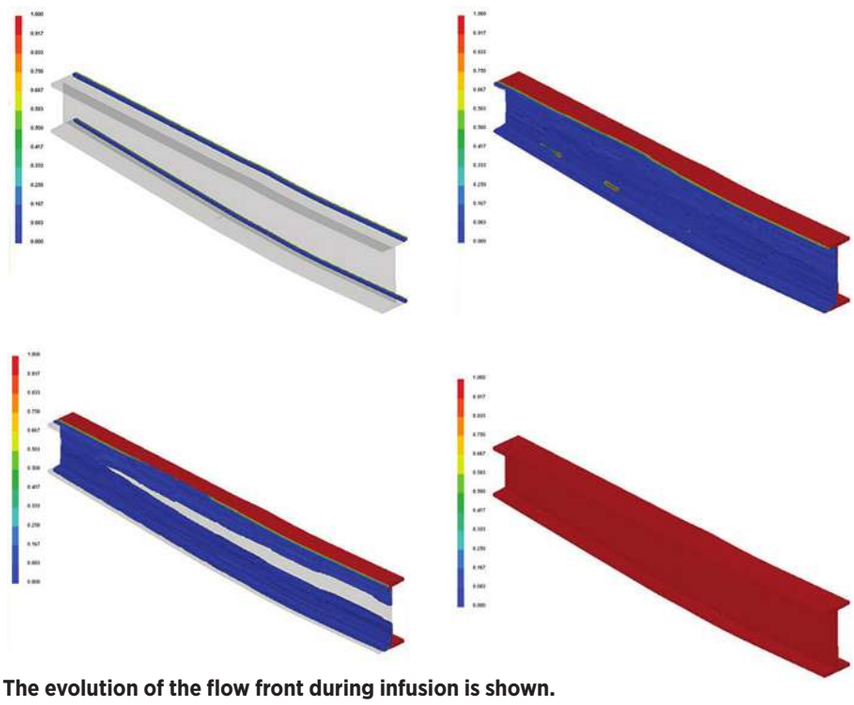
- Bottom/upper plates: K1 = 3.68E-12 m^2; K2 = 3.68E-12 m^2; and K3 = 1.5E-14 m^2
- "C" frames: K1 = 9.76E-12 m^2; K2 = 9.76E-12 m^2; and K3 = 4.24E-14 m^2.

To model the resin inlet, the researchers used a flow rate boundary condition with a maximum pressure. As long as the inlet pressure is below the maximum pressure, constant flow rate is imposed at the inlet and constant pressure equal to maximum pressure is imposed. This kind of boundary condition allows the proper description of pressure evolution at the inlet without modelling the full injection line from the resin pot to the mold.

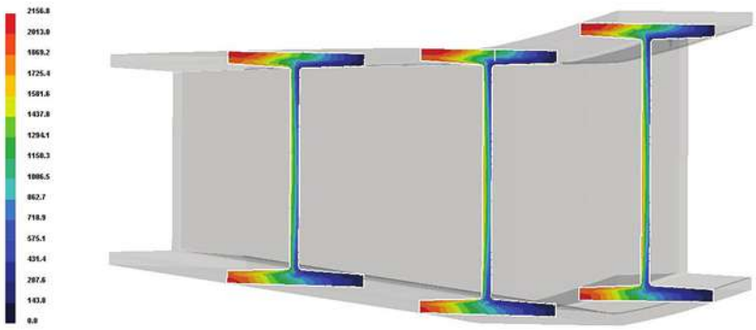
Three injection points (inlets) were defined on each channel used in the real experiment by Daher. Numerically, 1.11E-6 m3/s was imposed on each of those inlets with a maximum pressure of 1E5 Pa (= 1 bar). Two vents were defined numerically and were set to 0 Pa.

The current framework for viscosity modelling in the context of composites processing is based on the use of temperature and degree of cure or glass transition temperature as state variables. This implies that a viscosity development model needs to be coupled with a model of the cure kinetics, while the implementation of the model requires a series of cure kinetics characterization experiments in addition to the necessary rheological tests. This type of model works well in the context of autoclaving where the value of viscosity is important over a wide range of degrees of cure (from the uncured material up to gelation).

However, the role of a rheological model in the simulation of liquid molding processes is different, as viscosity is one of the parameters governing the filling/infusion stage during which the changes in degree of cure are relatively small. These small changes induce a significant increase in viscosity, which can eventually alter the outcome of the process. When models based on the use of the degree of cure are utilized, the accuracy of the simulation can be compromised by the fact that one of the underlying variables of the model has a small varia-



The evolution of the flow front during infusion is shown.



Representation of the filling times in three different sections.

Researchers found that the last-filled zones corresponded with good precision to dry spots identified on the actual part (shown).

tion during the process. This can result in usage of a model that is developed over a range of wide degrees of cure (from about 0 to 60%) only within a limited range (up to about 10%).

The approach adopted by INFUCOMP researchers overcomes this limitation by using the viscosity at a reference temperature as a state variable instead of the degree of cure. The reference viscosity follows its own kinetics.

Due to the higher permeability of the distribution medium, resin preferentially flows in this flow media. This phenomenon favors a transverse flow in the central part of the spar. Finally, infusion time (2157 s) is in good correlation with experimental results (2100 s). Moreover, the last-filled zones correspond with good precision to dry spots identified on the actual part.

Again, simulation results were in agreement with experiments and found to be valuable to understand and validate the infusion process. The results also help researchers to understand the simulation workflow and methodology as well as the monitoring capabilities.

This article is based on SAE International technical paper 2014-01-0965 written by Pierre Marquette and Arnaud Dereims of ESI Group; Michael Hugon and Guenael Esnault of Daher Aerospace; Anthony Pickett of the University of Stuttgart; and Dimitrios Karagiannis and Apostolos Gkinosatis of INASCO.

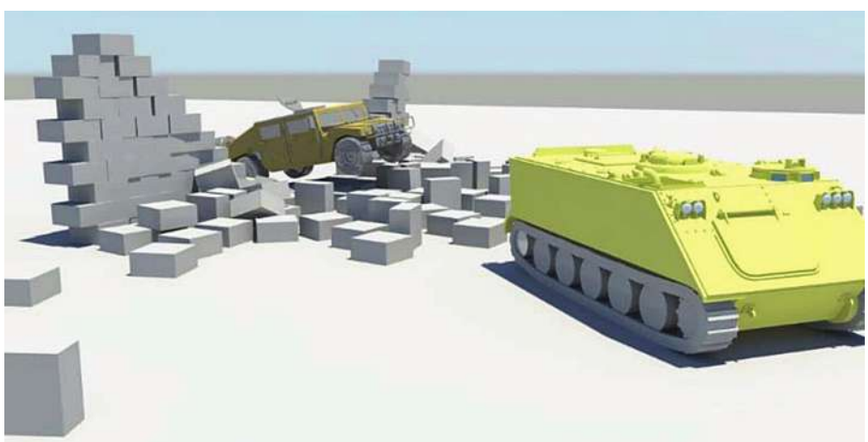
OFF-HIGHWAY SIMULATION

University of Wisconsin researchers develop mobility analysis tool for military applications

Despite the integral role that off-road vehicles play in combat and military operations, researchers do not currently have the ability to accurately estimate vehicle operational parameters such as forces, torques, and sinkage that a wheel or track on a vehicle experiences; investigate the interaction that occurs between a wheel/track and soft soil; and simulate a ground vehicle's ability to navigate complex off-road terrain.

Researchers at the **University of Wisconsin** recently developed a modeling, simulation, and visualization framework, called Chrono, aimed at enabling high performance, physics-based, analysis of ground vehicle mobility.

Military maneuvers, involving tactical formations and movements of wheeled and tracked vehicles across a landscape, provide the edge in combat for military units. However, scientists and engineers, who most often design the vehicle-weapons systems capabilities used in combat operations, are generally not included in the tactical planning process and must design vehicles based on expected mobility challenges. It is difficult and expensive to evaluate a vehicle's performance during a majority of military maneuvers using experiments. The Chrono framework provides an end-to-end mobility toolkit to simulate a variety



A brick wall was modeled in Chrono to represent a common obstacle that military vehicles face in an urban environment. The model is composed of a rigid terrain with a wall composed of 150 bricks. Bricks are modeled as discrete bodies with a friction coefficient of 0.4 along with a varying cohesion between bricks to model the concrete forces.

The muddy terrain simulation consisted of a 3000-kg (6600-lb) HMMWV and four rigid 60-kg (130-lb) wheels with treads. A bed of 200,000 objects of varying shape were created with a density of 1250 kg/m^3.

A rocky slope was modeled in Chrono to represent a common obstacle that military vehicles face in gravel hill operations. The terrain's slope varies from 14° to 20° and is composed of over 8000 unique rocks with a randomly generated polyhedral collision geometry.

of mobility models to investigate the performance of a vehicle during common military maneuvers, such as urban, muddy terrain, gravel slopes, and river fording operations.

A brick wall was modeled in Chrono to represent a common obstacle that military vehicles face in an urban environment. The model is composed of a rigid terrain with a wall composed of 150 bricks.

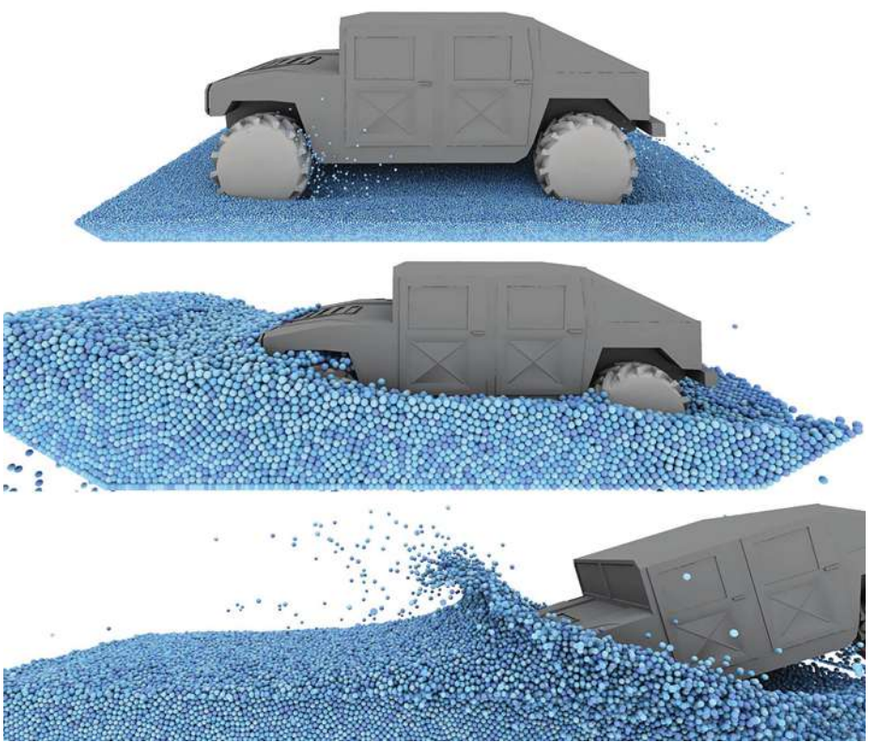
Six simulations were performed with the cohesion of the brick wall ranging from 5 to 30%. The tracked vehicle starts at zero velocity and ramps up to a steady state velocity of approximately 3.5 m/s. The tracked vehicle collides with the brick wall at approximately 3 s, causing the vehicle to lose velocity. For low levels of cohesion, the tracked vehicle is able to easily surmount the obstacle. As the cohesion increases, however, it is more challenging for the vehicle to destroy the wall. For example, the vehicle is completely immobilized when the cohesion of the brick wall is set to 30%.

The muddy terrain simulation consisted of a 3000-kg (6600-lb) HMMWV and four rigid 60-kg (130-lb) wheels with treads. Each wheel was rigidly attached to a fixed axle that was driven at a constant angular velocity of 1 rad/s. A bed of 200,000 objects of varying shape were created with a density of 1250 kg/m^3.

Using this model, the sinkage of each wheel along with the reaction forces at each wheel spindle can be measured. Further improvements will incorporate a suspension into the vehicle so that the forces between the wheel and the chassis can be computed. Additionally, a torque, rather than a constant angular velocity will be applied to the wheels so that the speed of the vehicle through the mud can be determined.

A set of simulations was performed to understand the vehicles' ability to traverse muddy terrain at decreasing values of inter-particle cohesion. The wheels of the vehicle were rotated at 1 rad/s and the sinkage and forward velocity of the chassis were measured. As expected, for lower cohesion the height of the chassis is lower as the entire vehicle sinks into the ground.

Three simulations were performed in Chrono with the slope of the hill ranging from 14° to 20° and terrain composed of over 8000 unique rocks with a randomly generated polyhedral collision geometry. The wheeled vehicle starts at zero veloc-



Vehicle traversing river section for various water heights. The first image shows a simulation with small fluid particles and a very low river depth. The second image shows a medium depth with the vehicle able to traverse the river. The last image shows a deep river and the vehicle creating a bow wave as it enters.

ity and increases velocity on a flat rigid terrain due to a constant torque applied to the rear wheels. The wheeled vehicle hits the slope at approximately 2 s, causing the vehicle to lose velocity. For steep slopes, the wheeled vehicle cannot surmount the hill and gets stuck. As the slope decreases, the vehicle is able to make it farther and faster up the slope.

Although most vehicles can handle rivers, it is desired to design faster and more efficient vehicles. Speed is elusive because of the severe drag and wave making properties implicit in box-shaped bodies. More and more power does not assure more speed, except in small increments, but rather serves to make bigger and bigger waves. Additionally, vehicles operating in water have the potential to become unstable.

The river fording simulation consisted of 200,000 frictionless spheres with a density of 1000 kg/m^3 in a deep channel. The HMMWV is kinematically driven through the channel with the rigid wheels rotating at a constant speed of 1 rad/s. The chassis and wheel geometry are made up of triangle meshes.

Simulations were performed with various amounts of particles and particle sizes to better understand how the vehicle interacts with the fluid as it enters and exits the section of river. These simulations show that when the height of the water is below the chassis, the water does not resist the vehicles motion and the wheels cut through easily. As the water level increases and it comes into contact with the chassis, a large wave in front of the vehicle forms as the vehicle pushes through the water. If the level is too high the fluid would likely enter the engine and crew compartments.

This article was written for SAE by Daniel Melanz, Hammad Mazhar, and Dan Negrut of the University of Wisconsin.

MANUFACTURING

Study shows multiple benefits of CO_2 cooling in composites drilling

The use of composite materials in aerospace and automotive applications has grown at a fast rate (and will continue to do so) due to the high strength and low weight of the materials.

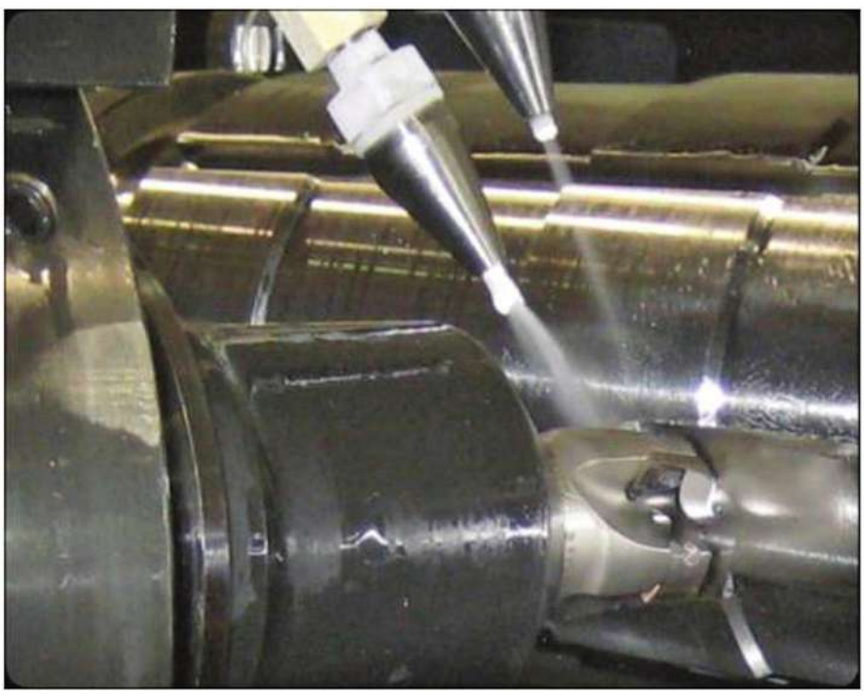
The benefit of using composite materials for applications demanding strength, flexibility, elimination of corrosion, at minimal weight is well documented. Using composites rather than aluminum in aircraft structures saves weight on the order of 20%. This weight reduction is combined with the ability to achieve aerodynamically more advantageous shapes through precision molding, resulting in better payload fractions and reduced fuel requirements.

Use of the material continues to grow despite its significantly higher raw material costs and relatively involved processing—frequently requiring expensive autoclaves or other pressure- and heat-producing devices to compact and cure the materials.

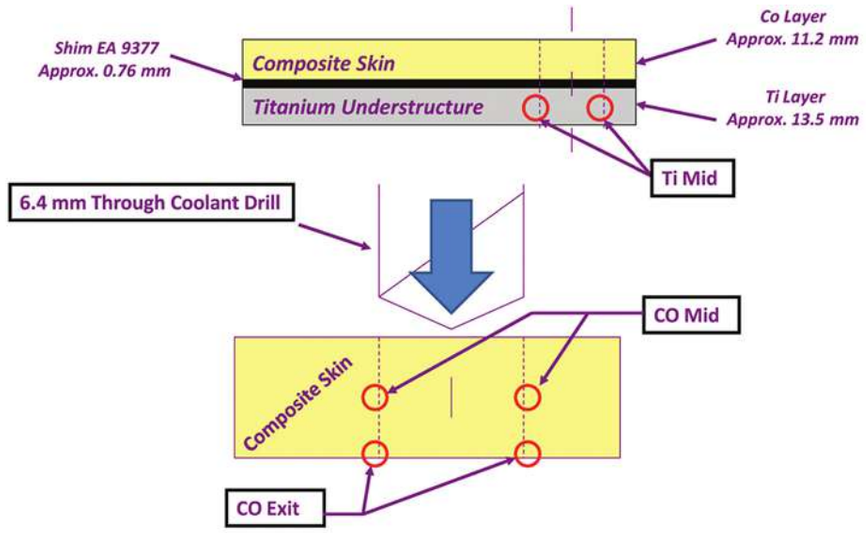
Another challenge of composites is their response to being drilled. This is especially true when the material is used in combination with a metal in a stack-up—e.g., composite and titanium. Drilling of the titanium layer(s) creates much heat, which can thermally damage the resin matrix of the carbon fiber reinforced plastic (CFRP) layer(s).

Through-tool CO_2 cooling.

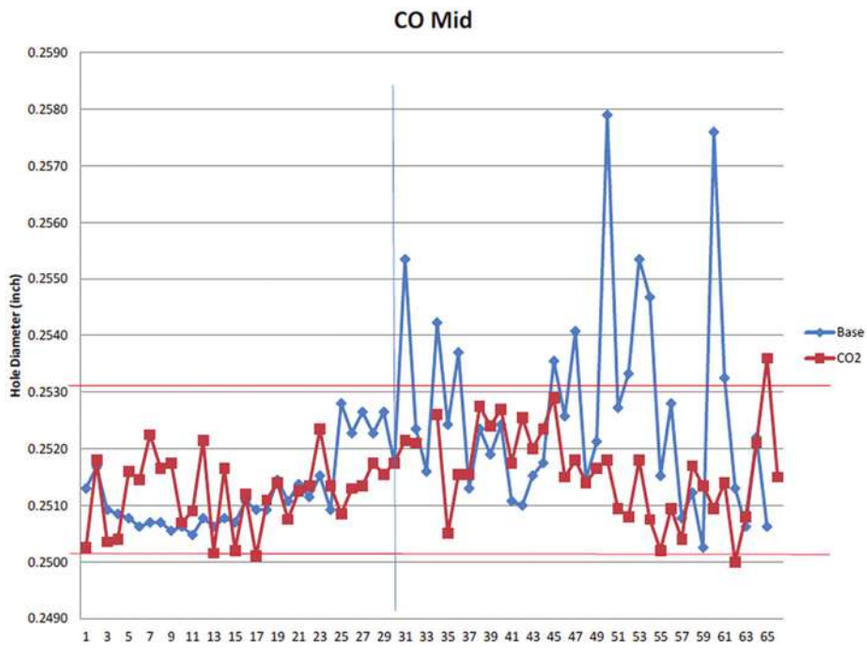
Heat is a key issue in nearly every machining operation, causing wear, reduced tool life, reduced processing



Cooling via CO_2 from an external source.



Depiction of a cross section of the CFRP-Ti stack-up, showing where critical measurements were taken during the testing (see accompanying graphs for test results). "Ti Mid" was taken at the midpoint of the titanium understructure; "CO Mid" was taken at the midpoint of the composite skin; "CO Exit" was taken at the exit point of the drill of the composite skin.



"CO Mid" hole diameter variation. Blue indicates conventional coolant, red the CO_2-based coolant.

speed, and limited throughput in addition to the issue of resin-matrix damage. Traditional liquid coolants, particularly petroleum-based ones, often do not provide enough cooling effect. Also, it is not feasible to clean liquid coolants or oils from large CFRP parts such as fuselage panels.

By using CO_2 through-tool cooling, which is a dry process, it is possible to protect both layers, researchers at **Cool Clean Technologies** have found through work supported by the **U.S. National Science Foundation** and **U.S. Department of Energy**. The work shows that CO_2 through-tool can significantly increase productivity while maintaining required hole tolerances in both the composite and Ti layers. In addition, improvements in tool life have been demonstrated with CO_2 through-tool cooling compared to either emulsion or dry drilling.

In CFRP-Ti stack-ups, the carbon fibers are very abrasive to drill, and significant heat is created in the drilling process. This damages the resin binders of the composite material. Drilling of the Ti layer produces an even more damaging chip, which can erode the corners and inner diameter of the drilled hole and therefore create a sloppy fit between the panel and fastener.

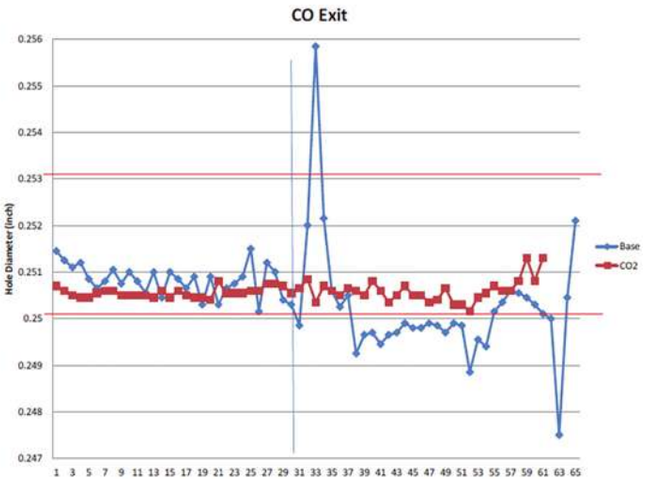
In aircraft, CFRP-Ti stack-ups are most commonly used for the fuselage. Thousands of holes, which are typically 0.64 cm diameter, need to be drilled through the stack-up in order to fasten the panels to the aircraft frame.

The cooling system used in the Cool Clean Technologies' research includes a cooling fluid consisting of CO_2 ice crystals, CO_2 gas, and in some cases air. It is sprayed directly to the cut zone where cooling is required. The solid CO_2 crystals, which are formed from the expansion of liquid CO_2, sublime, and flash to CO_2 gas. This conversion is capable of absorbing significant amounts of heat: approximately 127-207 kJ/kg.

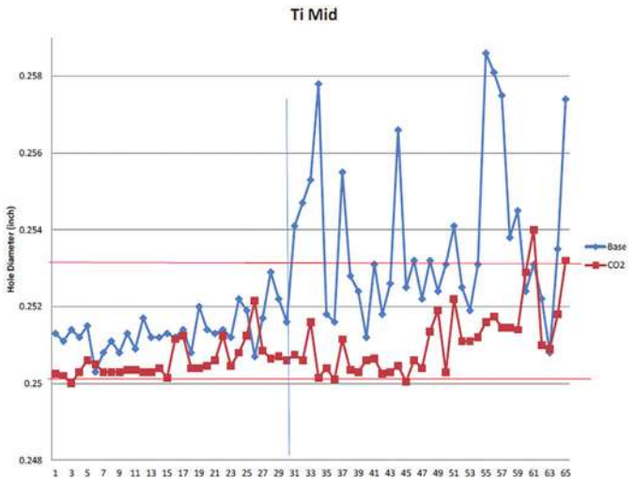
The system provides variable spray pressures, fluid lubricities, and compositions using a unique liquid-solid-gas spray. The solid crystals of CO_2 dry ice are delivered at a temperature of -79°C into the heat zone of the tool/work piece interface. This dry ice in solid form penetrates the vapor heat barrier to optimize heat transfer and thus the cooling effect. No other coolant technology is delivered in solid form, and hence no competing technology has the equivalent mass and momentum to impinge the heat barrier. The end results are:

- Solid dry ice (CO_2) crystals blasted into the heat zone to deliver significant cooling.
- Solid crystals have mass that can be forced through vapor barriers and heat zones.
- Cutting tool stays cool from the solid CO_2, keeping the cutting edge sharper to extend tool life significantly greater than conventional processes.

As part of their research, Cool Clean Technologies ran tests on CFRP-Ti stack-up drilling. The company found



"CO Exit" hole diameter variation. Blue indicates conventional coolant, red the CO_2-based coolant.



"Ti Mid" hole diameter variation. Blue indicates conventional coolant, red the CO_2-based coolant.

that CO_2 through-spindle coolant provides significant benefits over conventional flood coolant:

- Drill temperature reduction by as much as 27°C cooler.
- Hole size variability reduction: 0.025 mm vs 0.152 mm.
- Smoother surface finish: 22% smoother inside hole.
- Tool Life improvement of 10% or more while drilling the composite layer, and 2X or 3X while drilling the titanium layer. This relatively small increase in tool life can be significant, considering that PCD drills typically used to drill CFRP cost around $750 each.
- 100% elimination of post-machining parts washing processes.

This article is based on SAE technical paper 2014-01-2234 by Nelson W. Sorbo and Jason J. Dionne, both of Cool Clean Technologies.

MOTORSPORTS

Mazda reveals 2016 Global MX-5 Cup racer at SEMA Show

Following the recent unveiling of its fourth-generation MX-5 Miata (see http://articles.sae.org/13604/ and http://articles.sae.org/13504/), **Mazda** took the wraps off of a racecar version at the Specialty Equipment Market Association (**SEMA**) tradeshow in Las Vegas.

Based on the 2016 MX-5, the Global MX-5 Cup Car Concept shown at SEMA offers a glimpse of the car to be raced in a new Global Cup series, in North America, Europe, and Asia. Mazda is developing the racecar to be available as an affordable, turnkey, "ready-to-race" platform.

Starting in 2016, multiple Mazda Global MX-5 Cup series will take place around the world, all using identically prepared cars. Full details of the Global MX-5 Cup, including which countries will be involved and when the races will take place, will be announced as they are confirmed, Mazda says.

The Global MX-5 Cup will culminate at the end of 2016 with a Global Shootout at Mazda Raceway Laguna Seca in Monterey, CA, to crown the

Based on the fourth-generation Mazda MX-5 Miata, the Global MX-5 Cup Car Concept shown at SEMA hints at the car to be raced in a new Global Cup series, in North America, Europe, and Asia. (Ryan Gehm)

The Global MX-5 Cup racecar will be equipped with a 2.0-L SkyActiv-G four-cylinder engine. Mazda Motorsports plans to undertake a development period this winter to select the optimum tires, suspension, powertrain, and safety modifications. (Ryan Gehm)

A peek inside the Global MX-5 Cup Car Concept shown at the SEMA Show in Las Vegas. (Ryan Gehm)

series champion. The winner will receive, among other prizes, a one-day test in Mazda's Tudor United States SportsCar Championship SkyActiv prototype racecar.

"Because the MX-5 is inherently such a good car to drive, it is an ideal platform to learn basic and advanced race-craft, and this has made the professional MX-5 Cup series very successful to date," said John Doonan, Director of Motorsports for Mazda North American operations.

The Global MX-5 Cup racecar will be equipped with a 2.0-L SkyActiv-G four-cylinder engine. **Mazda Motorsports** plans to undertake a development period this winter to select the optimum tires, suspension, powertrain, and safety modifications. Final specs will be announced in 2015, says Mazda, when it is ready to accept orders for the 2016 series.

Technical partners for the car also will be announced at a later date. The Global MX-5 Cup racecars will be sold "ready to race" from a single supplier—a first for Mazda.

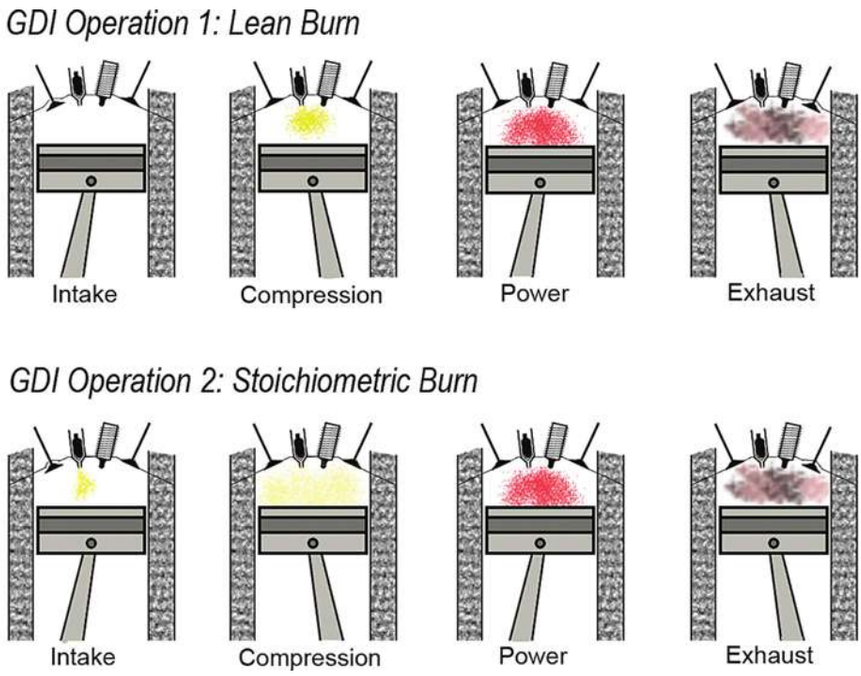
For 2015, the third-generation MX-5 will be used for its final season of professional racing in North America. (For 2016 and beyond, existing MX-5 Cup racecars will be eligible to compete in club racing only, the company notes.)

The 2015 Battery Tender Mazda MX-5 Cup Presented by **BFGoodrich Tires** will kick off at Sebring in March, and conclude at the Petit Le Mans Powered by Mazda at Road Atlanta in October.

Ryan Gehm

Next-generation GDI

Will new efficiency and emission rules mean major changes for gasoline direct-injection technology?



GDI operation modes.

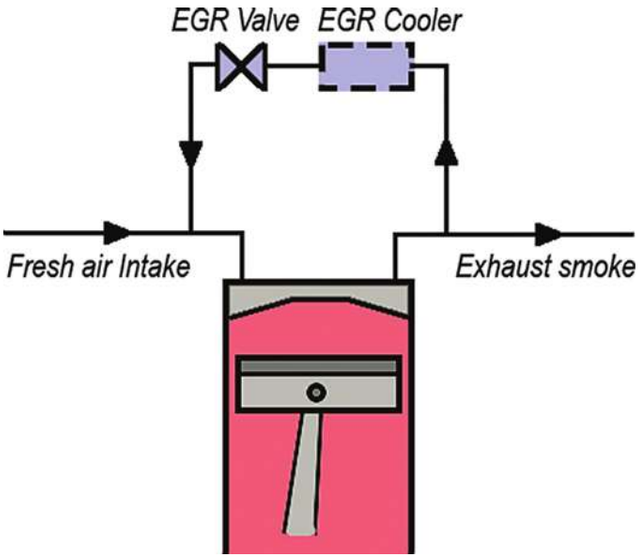
It has been rightly said, "a man refuses to move unless kicked in his hind."

Take for example the steep decline in the usage of carbureted engines during the '90s. The catalytic converter was mandated in new petrol-powered vehicles, which was incompatible with unregulated fuel-air mixture combustion, characteristic of carbureted injection. This eventually led to the discontinuation of carburetors and today every petrol engine employs the multi-point fuel injection (MPFi) system. Evidently, it was the new emissions regulations two decades back that was the "kick to the hind," rather than inherent inefficiencies of the traditional system as is popularly believed. We expect to see a similar trend today and in the future thanks to the stricter-than-ever emissions and efficiency legislations.

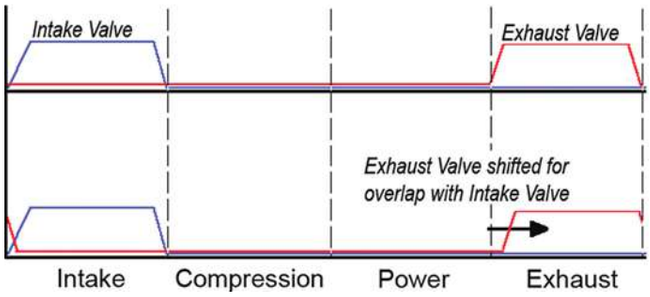
Most petrol engines today are port-injected whereas diesel engines have direct-injection. While port-injection allows a homogeneous charge to be used (which is always at near-stoichiometric mix, hence good emission characteristics with the effective three-way catalytic converter), stratified direct injection in a conventional diesel employs lean burn combustion to exhibit meager fuel consumption during low-moderate load conditions. GDI aims to utilize the best of both.

GDI (gasoline direct injection) is a cross between the petrol and diesel engine. In GDI, highly pressurized petrol is injected directly into the combustion chamber via common rail as in a diesel engine, whereas a conventional petrol engine has fuel injected into the intake tract. Another major difference is the lack of throttle valve in GDI. The throttle in a petrol engine controls the power output by restricting the flow of fresh air to the engine. Therefore, during low-medium load operation, the engine works against pumping losses from already low pressure in the intake tract as the throttle is partially blocking the path. GDI loses the throttle as the power is controlled by measured fuel injection for combustion.

GDI works in between the operation mode extremes: lean burn during low output scenarios like cruising/downhill, and stoichiometric/slightly-enriched during high load/hard acceleration/uphill situations. Dedicated fuel injectors inject directly into the chamber during intake stroke resulting in a homogeneous charge for the latter operation type, whereas for lean burning, fuel is injected just before ignition event in order to prevent knocking and pre-ignition in the abundance of air. Another reason for stratified charge combustion during lean burning is that the spark-plug vicinity should be fuel rich, guaranteeing a localized combustion away from the cylinder walls (which absorb heat from the cycle). Higher thermal efficiencies can be obtained by leveraging



Principle of external EGR.



Internal EGR (scavenging).

lean burn and direct injection to give higher compression ratios.

A GDI regime discards the conventional throttle valve of a petrol engine to eliminate pumping losses, and operates with a lean charge mix, which reduces fuel consumption drastically and enables higher compression ratios to churn out more horses at the peak with lesser average consumption. Performance? Check. Economy? Check. Emissions? If only it were that simple! Although CO_2 and unburned hydrocarbons are much less during regular operation, widely varied fuel mixture renders the three-way catalytic converter useless as it operates only in a narrow range of exhaust mix. As a result, NOx emissions are higher. Stratified charge combustion also increases the particulate matter (PM) emissions (soot).

Exhaust gas recirculation (EGR) addresses the issue of oxides of nitrogen to some extent. The presence of some amount of inert gas in the mixture reduces the combustion temperature and creates a partially inert environment chemically to hinder the generation of nitrogen oxides. On the other hand, reduced temperature and chemical un-reactivity discourages complete combustion giving away more soot (PM). Therefore, it has always been a trade-off between NOx and PM emissions for EGR calibrators, although it will not matter much in lean conditions, as there is already abundant oxygen for complete burn. Newer 'internal' EGR systems utilize the concept of incomplete scavenging by introducing overlapping open times of the intake and exhaust valves at the beginning of the intake stroke. This suctions of some exhaust gases back into the chamber along with the fresh flow of cool air.

Although advanced EGR systems with active particulate matter filter on the exhaust solve the problem of high emissions in GDI to some extent, the problem of escalated costs due to a high-pressure fuel delivery system and very high precision injectors is critical. Key enabling technologies in the market today like forced-induction (i.e. turbocharging/supercharging) and variable valve control (primary enabler of 'internal' EGR systems) have aided standard direct-injected petrol engines to be downsized without compromising on driveability and performance dynamics. The famous 1-L turbocharged GDI EcoBoost engine from **Ford** (this in-house development has brought several accolades for the automotive giant in the previous years) churns out 123 bhp and is small enough to be fit in the overhead storage compartment of an airplane. Not only that, the engine application is inexpensive, as we see in the Ford EcoSport launched last year in India. The ValveLift system in the **Audi** FSI (fuel stratified injection, Audi's proprietary GDI technology) engines allow a highly customizable driving experience as the engine can be switched to a low emissions and high economy mode during cruising and a punchy power-pitching mode for the enthusiastic driver.

Major automotive markets like USA and Europe and emerging markets like India and China are shifting toward eco-friendly vehicles. As a result, research focus of big car companies and OEMs is now geared toward minimal impact to the environment. On the other hand, complete/hybrid electric vehicle application is still too costly to see mass production in the current decade. Keeping that in mind and the close deadlines to meet optimistic emissions norms throughout the world, it is apparent that the optimization of the internal-combustion engine is the need of the moment. Looking at the good penetration of GDI in the market and the fact that major technologies are already in existence for further refinement, one can be certain that GDI is here to stay. Maybe in 2025, modern day MPFi petrol engines become obsolete as carburetors are today. But only time will tell. ■

This article was written for Mobility Engineering by Mr. Surojit Sen, Analyst, EXL Service, Noida, India.

Process management and benchmarking for trucks

Caterpillar India and Anna University of Coimbatore conducted a study to evaluate the adherence of process steps in each of the phases of New Product Development framework for Caterpillar's 40/50-ton rear dump trucks as well as competitive benchmarking and how the 40/50T stacked up against the competition.

New Product Development consists of eight phases, starting with the program strategy and concluding with physical production.

Caterpillar India and **Anna University of Coimbatore** conducted a study to evaluate the adherence of process steps in each of the phases of New Product Development (NPD) framework. They looked at the Caterpillar's development of 40/50-ton rear dump trucks and how Caterpillar's adherence of NPD processes paved the way for the successful production launch of its 40/50T products. Caterpillar India and Anna University of Coimbatore also looked at competitive benchmarking and how Caterpillar's 40/50T stacked up against the competition.

Product manufacturers are under increased pressure to grow revenues and improve operating efficiency. Challenges in meeting growth targets include changes in consumers' demographics, increased competition in mature markets, increased spending on services, and the rise of private labels and the low success rate of new brands. We are definitely entering the era of innovation. It is pervasive. It is influencing the way in which companies think about virtually every aspect of research; marketing product development; supplier and materials management; manufacturing; distribution; warranty and defect management; maintenance, repair, and overhaul; and product end-of-life and disposal. Innovation is global.

Innovation knows no boundaries. Its growth is being nurtured by active investments, grants and tax incentive policies of established, industrialized nations and emerging economies. Put in the context of the era of innovation, the "perfect product launch" and lifecycle management are now viewed in a different and expanded way.

Caterpillar India Private Limited manufactures off-highway dump trucks, front end loaders, hydraulic excavators, and backhoe loaders used in open cast mining, quarrying, irrigation, steel plants, cement plants, power plants in the field of construction and material handling. With the growing prospects in the emerging market and to establish Caterpillar's worldwide market leadership, the Off-Highway Truck group needs to launch a worldwide platform for the 40/50T to address both emerging market and developed market needs by providing our customers the best value proposition at a fair price. To address the pricing sensitivities in emerging markets it would be beneficial to leverage the lower cost of producing the emerging markets offering at the CIPL plant. The study scope addresses key customer, business, and regulatory requirements by delivering content that creates value, generating stockholder wealth.

Competitive benchmarking is the "production study" carried out by the OEM by comparing its class of its product to the similar class of product of the competitor. This will necessitate establishing the advantages and positive selling features with respect to performance over the competitor machines in the market. The two major factors of comparison are fuel consumption and productivity. The positive selling features include lesser fuel consumption per hour and higher productivity measured in fuel/ton ratio.

Based on the earlier mentioned New Product

Process management and benchmarking for trucks

770 / 772 Titan "X" Series	Base (Tender)	EM (Private)	Dev. Mkt.	ATT
Information Systems / Electronics				
Product Link				X
Fluid Level Monitoring			X	
Economy Mode	X	X	X	
Autoidle/Autoshutdown		X	X	
Messenger Display			X	
Advisor/CMPD Display				X
Tire Pressure Monitoring			X	
TKPH				X
Guardian				X
Ground Level ET Port	X	X	X	
TPMS				X
Cab and Operator Environment				
Tilt Cab			X	
Heated Mirrors				X
Power Mirror				X
Foot rest		X	X	
Hinged & Sliding RH Window			X	
Power Left Window			X	
Trainer Seat, Lap belt	X	X	X	
Seatbelt Indicator				X
HID Lights				X
ISO 5006 Visibility Package				X
1 WAVS Package				X
3 WAVS Package				X
EU Arrangement (incl. suspension)				X
Heater				X
Autotemp				
Air Conditioning				X
Double Floor				X
Radio Mounting Bracket		X	X	
Map Light		X	X	
Cigarette Lighter		X	X	
Deluxe Instrument Cluster		X	X	
Fuel Level Indicator - Cab	X	X	X	

770 / 772 Titan "X" Series	Base (Tender)	EM (Private)	Dev. Mkt.	ATT
Body				
Dual Slope Body	X			
Flat Floor Body				
8mm Liner (must select one)				
12mm Liner (must select one)				
16mm Liner (must select one)				
20 mm Liner (must select one)				
25mm Liner (must select one)				
50mm Rubber (must select one)				
100mm Rubber (must select one)				
Various Sideboards				
Safety				
Retractable Ground Level Access System				X
Improved Brake Slope Holding Capabi	X			
Fire Supression Zone	X			
Self Adjusting Back-Up Alarm (audio/v	X			
Performance				
ARC	X			
Extended Life Disc Brakes	X			
Cold Weather Starter				X
Engine Heater 120V				X
Engine Heater 240V				X
Diesel Fuel Heater				X
Compression Brake				X
Exhaust Body Heat Routing	X	X	X	
Exhaust Muffler				X
Exhaust Body Heat/Muffler Diverter				X
TCS				X
ECPC	X			
Advanced Shift Control		X	X	
Serviceability				
Ingress / Egress Lights		X	X	
Engine Compartment Lights			X	
Side Work Lights			X	
High Speed Oil Change		X	X	
Ground Level Grease Fittings		X	X	
Groeneveld Auto Lube Power Supply Ready		X	X	

The study details the voice of the customer (VOC) and voice of the business (VOB) analysis carried out upfront before starting the NPD program.

Development Framework and Competitive Benchmarking, the research objectives of the study are:

- Evaluate the adherence of process steps in each of the phases of NPD framework.
- Identify and verify metrics in each of the phases of the NPD framework.
- Identify VOC and VOB characteristics and verify whether those are met in each of the phases.
- Plan and build pilot machines of the new model of trucks and evaluate the performance of pilot validation in the customer mines sites.
- Carry out production studies of the new model of trucks with the competitor machines and generate Production Study data to substantiate the advantages of the new trucks over the competitors.
- Verify the readiness deliverables in all functions for the successful New Product Production Launch and
- Document lessons learned and create scope for further improvements in the future programs.

In the present study, descriptive design is used, taking into consideration the nature of this research work. Singh (1980) has defined descriptive research as a design to explain the characteristics of the variables per se. A descriptive study is normally employed in situations where it is necessary to describe and interpret "what is" kind of problems. It is concerned with conditions or relationships that exist, opinions that are held, processes that are going on, effects that are evident, or trends that are developing.

The research utilizes the case study approach to gain a detailed understanding of the various processes in the NPD management system in Caterpillar India Private Limited. A detailed study has been undertaken at each stage of the NPD process. As a part of the study, a structured survey instrument has been developed to gather information from the customers to improve the design of the products.

The study concludes on the successful introduction of 40/50T off-highway trucks to the growth markets. The study provides benefits of following the rigorous NPD process. The study details on the voice of the customer (VOC) and voice of the business (VOB) analysis carried out upfront before starting the NPD program, as shown in the figure.

The study rolls out the 8 phases of the Caterpillar NPD process and the metrics that govern it. It also details about the elaborate tools used in the NPD process and the benefits that arise due to following those tools. Caterpillar India and Anna University of Coimbatore's study unwinds the strategy behind introducing 40/50T off-highway trucks in growth markets and its impact on Indian economy and growth.

As a result of the study, the lessons learned and conclusions were:

- Adopt revitalized NPI early in NPD management program.
- Better utilize NPD tools.
- Team member training.
- Make commitments based on data.
- CPPD (Concurrent Product and Process Development) required to ensure all teams have all the relevant data required and understand whom to go to if they don't have the data.
- Ensure that the needed NPD tools are understood and put into place during NPD program.
- Ensure that all resources are in place and engaged prior to launch of the program. Successful programs require that all resources are available and easily approachable. ■

This article was adapted from a paper written by Saravanan Gopal, NPD Program Manager, Caterpillar India Private Limited (shown) and Dr. P. Vikkraman, Associate Professor and Department Head, Anna University of Coimbatore.

Integrated automotive gateway can enable connected cars

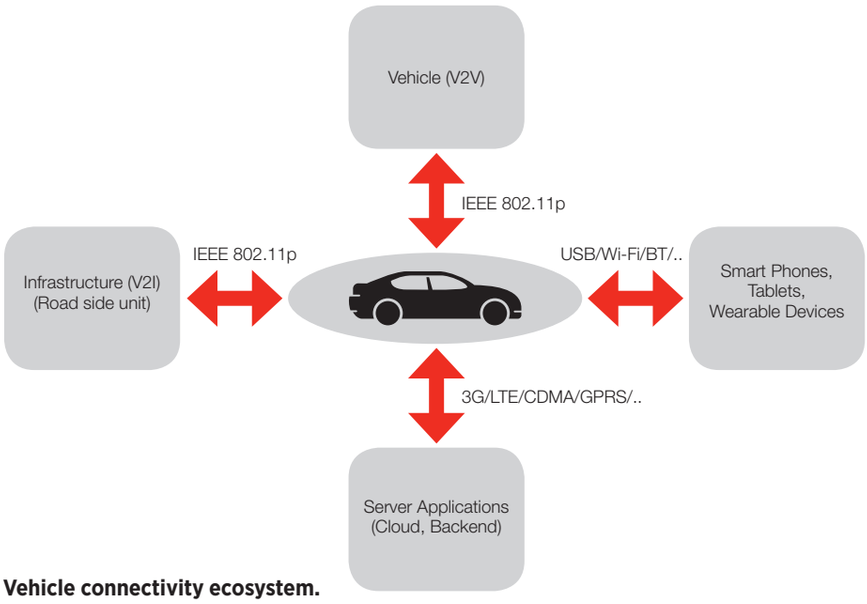
Technology developed by Tech Mahindra for vehicle-to-infrastructure and vehicle-to-vehicle communication provides a blueprint for creating a gateway that will help achieve seamless V2X mobility.

Connected-car technology has become a key differentiator for carmakers and and their Tier 1 suppliers. One of the biggest challenges connected cars pose is the integration of information and consumer electronics into the car and ensuring connectivity among them. Connected car applications such as telematics, driver assistance, and infotainment require seamless connectivity to and from the vehicle.

Modern cars are built with embedded computers called ECUs (electronic control units) that are further connected to sensors for data acquisition. The in-vehicle network is further divided into sub-networks such as CAN (controller area network), MOST (media-oriented safety transport), and FlexRay. The choice of the bus network depends on the communication requirements of the connected ECUs and the baseline vehicle platform out of which a new vehicle line is derived.

Moreover the vehicles of today are able to exchange data with external sources via Bluetooth, Wi-Fi, 3G (third-generation), and LTE (long-term evolution) networks. The advent of V2V (vehicle-to-vehicle) and V2I (vehicle-to-infrastructure) communication has increased this trend.

In addition to communication inside the vehicle, a robust vehicle communication gateway is important to establish seamless connectivity to conditions outside the vehicle. While the communication network inside the vehicle is stable, V2I and V2V communication to the outside is undergoing rapid change.



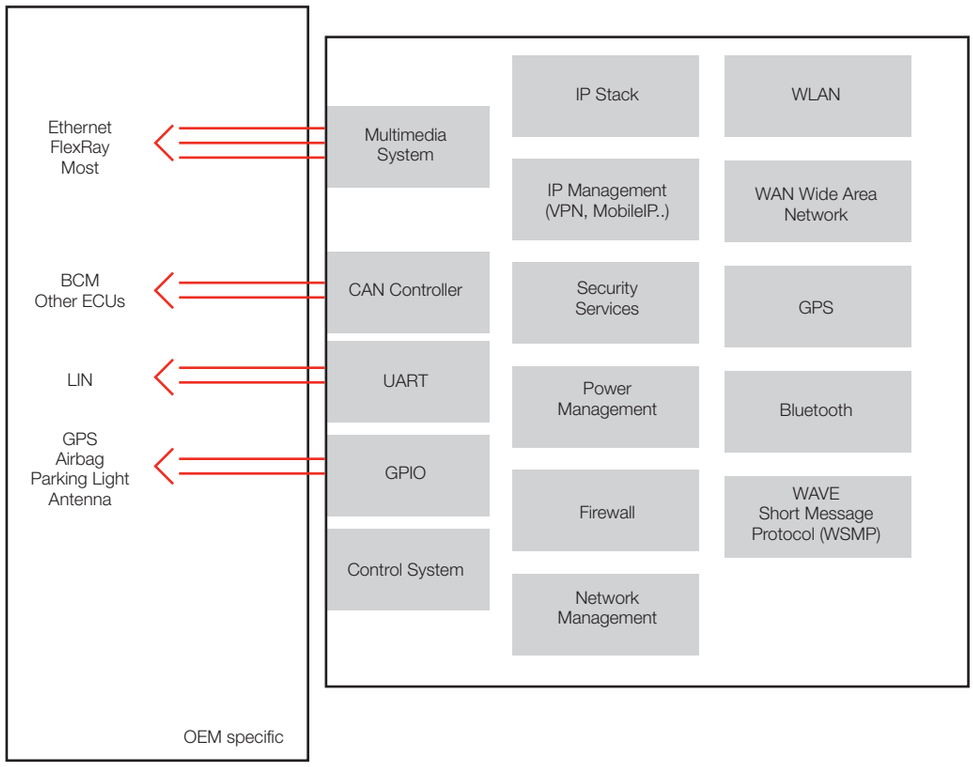
Vehicle connectivity ecosystem.

Vehicle gateway challenges

With advancements in telematics, connectivity challenges in vehicles have also changed drastically. The vehicle gateway of the future should be designed to address the following challenges:

1. Support multiple networks and provide secure wireless connectivity for/between vehicles and infrastructure
2. Provide secure, intelligent switching between different networks
3. Sense, select, and switch to best available network automatically based on user-defined policies

Integrated automotive gateway can enable connected cars



Automotive gateway system architecture.

4. Create a mobile hotspot for wired and wireless devices in and around the vehicle
5. Support various IP devices in the vehicle
6. Support upgradeability for current and future networks
7. Provide secure and reliable communication for all connected devices.

Vehicle internal networks are now more connected to external devices, thereby exposing the internal network to the outside world. The evolution of V2V and V2I communication has increased data exchange with external resources via Wi-Fi, 3G, and LTE networks.

Vehicles are no longer closed networks; they are potential targets for remote attacks. In-vehicle networks are safety-critical, and any access to an in-vehicle network may have serious safety implications. Therefore, both internal and external communication networks must be secured.

With the increased complexity of telematics services and applications, the big challenge is not about providing a platform with extensive features, but creating a future-ready vehicle gateway that has the flexibility to adapt and accommodate rapid changes and the ability to support new functionality that holds the key.

Integrated automotive gateway blueprint

The automotive gateway should provide a secure communication for data exchange, both onboard as well as off-board. The gateway proposed by **Tech Mahindra** is directly involved in supporting various mobility and safety applications that run either inside the vehicle or those hosted on a mobile or off-board platform using remote servers. The company is focusing its development on the concept of an "automotive gateway architecture" blueprint and its realization. The gateway supports various short-range communication systems for connecting to personal devices such as mobile phones, tablets via Bluetooth, Wi-Fi, and UART (universal asynchronous receiver/transmitter). To connect to the cloud via the Internet, the gateway supports long-range communication systems such as GPRS (general packet radio service), CDMA (code division multiple access), LTE, UMTS (universal mobile telecommunications system), and GSM (global system for mobile). IEEE 802.11p is supported for V2V communication and communicating with road-side units. The gateway architecture has to be designed for supporting connectivity with known and unknown entities.

Known entities could be trusted entities such as firmware over-the-air (FOTA) servers, telematics services over back-end servers, or service/plant diagnostics over Wi-Fi, while unknown entities refer to untrusted ones such as third-party applications, open cloud connections from in-vehicle devices, and smart devices brought into the vehicle connectivity network.

The software architecture is designed with a plug-and-play approach to ensure support to new connectivity changes without altering the core software.

The system architecture under consideration directly relates to connectivity mechanisms. The physical layer is 802.11p instead of 802.11 b/g/n. The vehicle gateway carries two stacks, namely:
1. IPv6 (Internet protocol version 6) based TCP/UDP (transmission control protocol/user datagram protocol) for supporting non-safety applications like e-toll,

traveler info, construction management, commercial vehicle operations, etc.

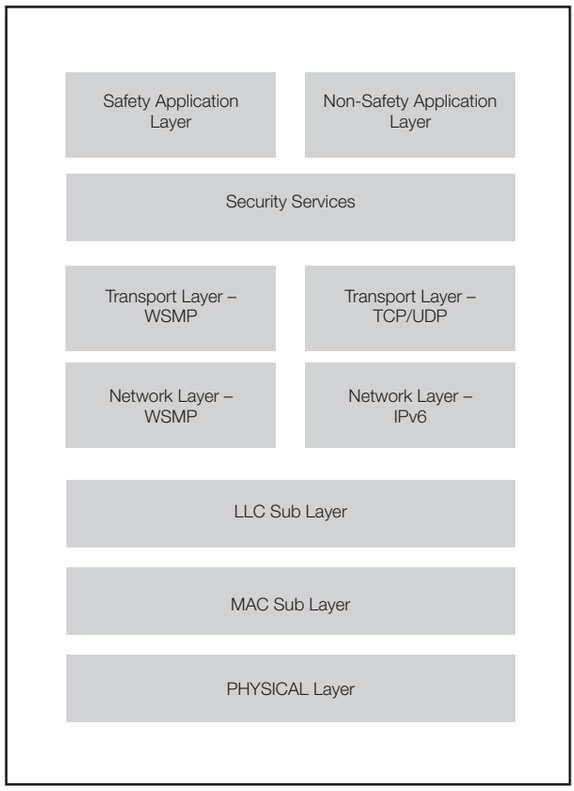
2. WSMP (wave short message protocol) stack for safety applications such as curve speed warning, V2V-sensor data exchange, left-turn assistant, etc.

IPV6-based TCP/UDP will enable a secure and seamless connection from gateways to portal/Internet. WSMP allows applications to directly access/control physical layer characteristics without access points for ad-hoc communications.

The gateway must support multiple PHY (physical layer) requirements (connect to smart services inside the vehicle and 3G networks for telematics) to enable a range of infotainment and telematics applications.

To ensure V2X, telematics, and infotainment functions, the gateway solution must support and implement the IEEE 802.21 specification for "handover between heterogeneous networks" to ensure seamless handover between network switches and controls when the vehicle is on the move.

A true future-ready automotive gateway should be able to send IPv6 packets over 802.11p and 3G networks with a seamless vertical handover. Seamless handover happens when the vehicle is moving through and different WLAN (wireless local area network) and 3G networks, constantly switching between heterogeneous networks for always best connected services.



Automotive gateway system stack.

Security model of the gateway

Initially, in-vehicle networks were designed to operate in a closed environment where security was not a major concern. Considering that the gateway must support V2X communication and a number of external interfaces to in-vehicle networks, threat levels are perceptibly higher with consequent increases in safety and security requirements.

The security mechanism in the gateway must be designed to contain attacks by rooting the security mechanism on hardware with crypto algorithms. This ensures that sensitive information such as cryptographic keys is not vulnerable to software attacks. The hardware security module protects the key store, acting as crypto hardware and supporting well-defined software interfaces. Hardware-based security is proposed to handle ad-hoc message exchange load in varying high-speed road traffic conditions.

The security module must be designed for use in combination with vehicle manufacturers' security policies. Additionally, the gateway security mechanisms must be clearly intended for generic connectivity to vehicular networks as operational environments change dynamically.

Enabling future convergence

Data encryption and the security of the telematics back-end have been primary concerns in automotive telematics. The automotive gateway will act as a convergence point for the cooperative networks of the future, which will support a variety of safety critical and mobility applications that either run inside the vehicle networks or are hosted on smart devices or on remote servers. In next-generation telematics, in which vehicles will connect ad-hoc to random entities and route data through unknown networks along the way, all-round vehicle security will be of paramount significance.

The automotive gateway is expected to play a significant role in vehicle security in addition to its traditional data gateway functionality. While the future of connectivity infrastructure is speculative, we know the broad outlines of what might transpire. The automotive gateway has been envisioned based on these broad outlines. The adoption of the gateway approach will, ultimately, ride on the ease of providing seamless connectivity over the vehicle's mobility envelope, safely and securely. ■

This article was written for SAE International by Karthik P. Rao, Consultant, and Balakrishnan Muthukrishnan, Principal Consultant, for the Connected Cars Practice at Integrated Engineering Solutions, Tech Mahindra.

Hard to answer

Technical and personal issues make it challenging to link smartphones to vehicles.

by Terry Costlow

Linking vehicles and smartphones is critical across all vehicle classes, said Broadcom's Richard Barrett.

Human-machine interfaces (HMIs) are quickly evolving as smartphones and apps enter vehicles. Developers are allowing multiple ways for drivers to interact with apps and phones, knowing that a well-designed HMI can be a significant differentiator while a problematic HMI can become fodder for highly-publicized criticism.

The tightening link between cars and consumer devices is challenging vehicle designers who must adopt consumer technologies for control. Most executives agree that a range of control and display technologies will be needed to manage apps and phones.

"We believe HMIs will follow a multi-modal approach," said Nick Lontscharitsch, President of **Preh** Inc. "OEMs don't know who's going to be behind the steering wheel—someone who's 18 or 80. Steering wheel switches, touch screens, and voice will all be in the mix."

The challenge for design teams is that they need to mimic popular functions such as texting without endangering the public. Consumers focused on phones fall into fountains or crash into poles while walking, but they still want similar capabilities as they roll down roadways.

"A recent report suggested 80 percent of consumers expect the connected car of the future to provide the same connected experience that they are used to at home, work, and via their mobile phone," said Hans Roth, Director of Technology at **Harman** Infotainment Division. "Accident numbers are rising in developed countries, and it is thought using smartphone devices is a likely factor."

Psychological training

The vast differences in user preferences and technical skills require a wide-ranging approach to HMIs. Design teams are leaving no stone unturned in their attempts to meet these divergent demands.

"We work with psychologists to help us determine how usable software is, whether it's easy to handle or distracting," said Ingo Krueger, Business Unit Director, Cockpit & Mobility Systems at **IAV Automotive Engineering**. "We also run clinics with young and old people, males and females, in school and retired, to figure out what works and what doesn't."

The need for multiple input devices is highlighted by tasks such as controlling music. Voice works best for some tasks, while conventional knobs and buttons still work well for others.

"Voice recognition might be better suited for complex tasks like finding a particular song or contact in a large library or directory, while a mechanical button might be better suited to accomplish simple tasks like skipping to

the next track on a playlist," said Michael Tschirhart, Human Factors Technical Fellow at **Visteon**.

While engineers and marketers grapple with control challenges, they must also examine options for displaying information from phones. Some OEMs want a distinct look and feel for their HMI, but they must also show smartphone apps on in-vehicle displays.

"Display sharing will be critical for all future vehicles," said Richard Barrett, **Broadcom**'s Director of Wireless Connectivity. "The reasons are compelling. In higher-end vehicles, people will want to do things with their phones and have them linked to the vehicle display. In lower-end vehicles, this allows companies to offload a lot of technology that would otherwise have to be in the car—things like navigation and music."

Preh feels that many different control techniques must be combined to meet evolving requirements.

Ready to share?

There's a strong push to link smartphone displays to center stack screens so phone users see an interface they're familiar with. A number of techniques are vying for acceptance as OEMs quickly employ display sharing. **ABI Research** believes that smartphone integration using MirrorLink, **Apple** iOS, **Google** Android, or another alternative will be in 30% of new vehicles by 2019.

System designers will generally be able to support multiple options for display sharing just as they support multiple smartphone operating systems. That's because all the protocols have fairly small differences.

"All of the specifications are con-

HMIs must provide information that drivers want without compromising safety, according to Harman.

Infotainment/HMI the focus of March webcast

Consumers increasingly expect robust connectivity options when inside their vehicles, be it through dedicated infotainment and navigation systems, or via smartphones, apps, and other consumer devices brought into vehicles. Design teams know that enhanced infotainment capabilities—in addition to a well-designed human-machine interface (HMI)—can be a significant differentiator in the marketplace, while less-than-expected connectivity and a problematic HMI can become fodder for highly-publicized criticism.

Developers are leaving no stone unturned in their attempts to meet the vast differences in user preferences and technical skills. The need for multiple input devices is generally understood, as voice works best for some tasks, while conventional knobs and buttons still work well for others. *Automotive Engineering* will host a special technical webcast in March on the topic "Next-gen infotainment and interfaces." During this free 60-min webcast, experts will discuss the latest in next-generation infotainment systems, HMI advances that improve the user experience and enhance safety, as well as what capabilities can be expected in the years ahead.

Webcast attendees will be invited to interact with the experts during a Q&A segment.

Visit www.sae.org/webcasts for more information and to register.

Hard to answer

IAV performs a broad range of studies to determine what's safe and useful in an HMI.

solidating on similar hardware and software requirements," said Andrew Poliak, Global Director, Business Development, for **QNX Software Systems**. "OEMs will be able to support several projection modes."

While the technical challenge is fairly straightforward, myriad other issues will help determine how extensively display sharing will be deployed. Driver distraction is a dominant factor. Some observers feel that only a few apps should be shown on the vehicle's displays.

"We think three to five functions can be mirrored safely without distraction," Lontscharitsch said. "They should be freely programmable."

Who's in command?

OEMs are also reluctant to give up control functions. HMIs are seen as a critical differentiator, so automakers want to control these interactions, giving drivers a unified experience. Display sharing can help OEMs trim costs by offloading tasks to the phone, but that may not be a solid strategy in higher-end vehicles since the apps' interface changes the HMI's look and feel.

"While mirroring systems might be acceptable in entry-level vehicles, for mid- and high-level vehicles this is up to now not feasible," Roth said. "OEMs want to provide their own look and feel also as a differentiator and are unlikely to accept mirroring systems. Solutions inspired by Apple's iTunes and Google's Play Store, such as **Ford**'s Sync Applink, **GM**'s MyLink, or **BMW**'s Connected Drive, communicate with the car's infotainment system, allowing drivers to access limited online services such as making restaurant reservations."

That's a major challenge for automakers. "All OEMs are struggling with how much of the brand they want to give up," Poliak said.

Compatibility is another challenge for automakers. Phones change continuously, while vehicle systems are fixed well before cars roll off the production line. The more phones interact with vehicle infotainment systems, the higher the likelihood of problems.

Voice and touch inputs are among many control techniques being deployed by Visteon.

Elektrobit makes map data available to give drivers a view of the road ahead.

"A big issue for OEMs is that there are so many smartphones out there, and not all smartphone suppliers are careful about implementing standards," Krueger said. "If someone buys a cheap smartphone that doesn't completely fulfill the Bluetooth standard, specific functions may cause issues that are the fault of the phone, but the OEM is the one that has to deal with the complaint."

Adding the ability to upgrade vehicle software is one way to reduce the number of issues related to connecting vehicles and rapidly-changing phones. Car buyers accustomed to getting new phones every couple years are going to want to link them to vehicles that they keep far longer. That's prompting a lot of interest in firmware over the air updates.

"One thing that's clear is that vehicles need to be upgradable," Poliak said. "People expect to be able to add functions just like they can upgrade their smartphones."

Putting things in context

As human-machine interfaces (HMIs) manage more functions, they're going to need to be smarter about presenting options to drivers. Context is an important factor. When the car is moving, many apps shouldn't be running on the vehicle's display.

"One challenge that comes with display sharing is that content must be relevant to the vehicle," said Richard Barrett, **Broadcom**'s Director of Wireless Connectivity. "You want to enable things like navigation, playlists, and some text messaging, but you don't want to permit streaming video to the display."

Within this trend to provide data that's relevant to drivers, there's also a push to employ apps that make decisions based on user preferences. Systems can combine information from the vehicle, Internet sites, and navigation data to help give drivers input that will help them make decisions.

"People need to build context-sensitive HMIs," said Artur Seidel, Vice President of Automotive Software at **Elektrobit**. "For example, a smartphone app knows you prefer **Shell** gasoline. When the car's running low on fuel, the app can tell you you're low and that there's a Shell station on your route."

The HMI itself is also evolving to make it simpler for drivers to accomplish goals other than driving. Voice-recognition systems are beginning to shift from set commands to a more conversational approach.

"Voice is becoming more mainstream as it gets better and better and moves to natural language. When you say 'I'm hungry,' it will find restaurants," said Manuela Papadopol, Global Marketing Director at Elektrobit. "Natural language is definitely going to become mainstream. Still, you need redundancy on speech."

This sort of redundancy is often viewed as a cost-adder. But adding an option in an HMI can make the difference between a user experience that ends well and one that ends with frustration. Most user input devices are fairly inexpensive, and the cost of making an existing switch perform multiple functions is also low.

"I'm not sure that a multi-modal approach truly adds costs," said Nick Lontscharitsch, President of **Preh** Inc. "If the HMI is a major differentiator, does anyone care about a $10 price increase?"

Terry Costlow

Getting a grip on AWD efficiency

The safety and performance benefits of all-wheel drive are undeniable, but so are the penalties of added weight, friction losses, and complexity. Clever axle disconnects and E-axles are driving future AWD developments.

by Lindsay Brooke

Jeep brand credibility rests on off-road capability, even though most customers will never take their 2015 Renegades on the trail. Driveline engineers must balance "soft road" and off-road performance requirements in the popular global CUV segment with the push for greater fuel efficiency through driveline friction reduction and lower-mass systems.

All-wheel drive is becoming a must-have feature for drivers who face slippery roads and daunting grades in winter. The growing popularity of the technology is fueled by the worldwide boom in B- and C-segment crossover utilities. Globally, AWD production volumes are expected to increase 6% annually through 2020, according to **Magna Powertrain** Global Production Manager, Ron Frawley. In the northeastern U.S. and upper Midwest, and in Canada, AWD can penetrate up to 70% of sales volume, depending on vehicle model, while sales may barely reach 15% in regions with more moderate climates and topography.

Along with its all-weather/all-season capability, AWD also offers performance attributes on dry pavement, optimizing the tractive force of four driven wheels rather than two. But with its inherent dynamic and safety benefits come challenges.

AWD typically reduces vehicle fuel efficiency by up to 5% (typically 1 to 3 mpg), compared with a 2WD baseline, Frawley noted. And that's got the industry's powertrain engineers and vehicle planners aggressively searching for solutions, said Dave Leone, **GM**'s Executive Chief Engineer for Luxury and Rear-Drive Vehicles.

"System weight and the drivetrain parasitic losses associated with AWD are what everybody is working hard to reduce," Leone told *Automotive Engineering* during the 2014 Los Angeles Auto Show. "The weight penalty of a standard AWD system is about 90 kilos (about 200 lb) versus a comparable rear-drive car; that's an order-of-magnitude. And AWD is expensive. So our ongoing focus is on how to reap the benefits without the pain."

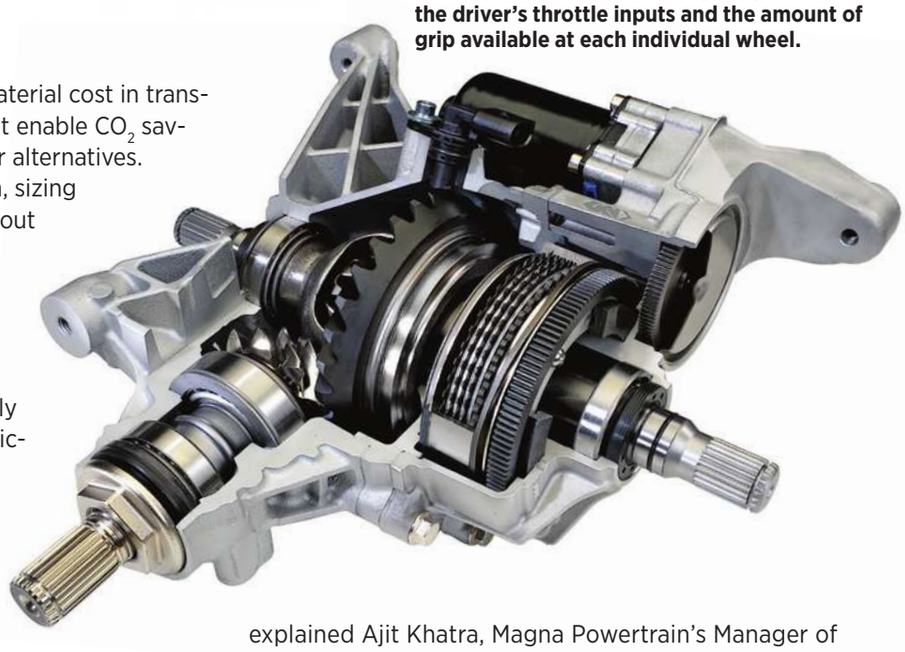
It's not a stretch to state that **Audi** wrote the book on AWD with its Quattro system and the company's Board Member for Technical Development, Dr. Ulrich Hackenberg, said his engineers are "working intensely to bring the all-wheel drive into our CO_2 emission-reductions program."

According to Dr. Hackenberg, **VW**-Audi is developing AWD systems that are "fully controllable per wheel, with axle disconnection [no torque transfer to the secondary axle] and re-connection based on the specific driving situation." In a brief interview at the L.A. show, he said he expects future AWD systems to eventually employ e-axles—"electric motors in the rear or in the front, in addition to the combustion engine." And, he said mass will continue to be extracted through careful component and systems development (wall thicknesses of case castings precisely tailored to stresses and loads, for example), and potentially through premium materials as well.

But light alloys such as magnesium (used for decades by VW for gearbox housings) to replace today's aluminum driveline castings means higher cost.

"There's no free lunch in this business—but in some cases that additional cost is well worth it as we work to comply with 54.5 mpg by 2025," Leone noted. He explained every GM vehicle development program is viewed in terms of dollars per gram of CO_2 saved over the life cycle of the vehicle. Engineers thus look at how many dollars they must spend to save each gram of CO_2 for

GKN Driveline's latest axle-disconnect system for A- through C-segment utilities underpins the Jeep Renegade and its 2015 Fiat 500X platform mate.



Sophisticated electro-mechanical rear drive modules featuring integrated, electronically-controlled active couplings are the foundation of "smart" axle-disconnect AWD systems going forward. Shown is GKN's ETM rear axle differential that launched in the Jaguar XK and XF "R" performance models. Its dedicated ECU uses proprietary IPM software to constantly monitor torque requirements and manage an electric motor that handles clutch actuation. The system works without driver intervention and continuously adapts to both the driver's throttle inputs and the amount of grip available at each individual wheel.

150,000 mi (241,400 km). Additional material cost in transfer cases and power take-off units might enable CO_2 savings at a lower cost per gram than other alternatives.

In terms of designing the mechanism, sizing gears and bearings for example, "it's about designing to the duty cycle—but not overdesigning," offered Robert Genway-Haden, Global VP Product Technology – AWD Systems at **GKN Driveline Americas**. "Even in non-disconnecting systems we're looking closely at everything that can reduce weight, friction, and drag on the system. Even fluid levels and different viscosity fluids are important."

CVT-like differential performance

Recent vehicle introductions show the path of AWD systems co-developed with powertrain and driveline suppliers—a space that is becoming increasingly crowded in terms of intellectual property and patent activity. **AAM**, **BorgWarner**, **Dana**, GKN, and Magna Powertrain, **Schaeffler Group**, and **ZF** are, in the eyes of a **Ford** program manager, "the predominant players in the powerflow competition" to further innovate, evolve, and refine the control electronics and internal mechanisms, including bearings, seals, and lubricant strategies, that will help improve system efficiencies. "Axle disconnects are the hot technology in the next product cycle," the engineer (who asked not to be identified) told *Automotive Engineering*.

Much of the AWD systems space, in terms of volume, is occupied by proven performers. **BMW**'s 2015 X4, for example, marks the 20th vehicle application for Magna's Actimax AWD "active" transfer case, which is branded XDrive by BMW and is used across the X-Series utility range. A two-speed version is used in the **Jeep** Grand Cherokee and **Chevrolet** Silverado. Fully active transfer cases "perform like a continuously-variable differential," explained Ajit Khatra, Magna Powertrain's Manager of Vehicle Verification and Testing, during a winter-test session attended by *Automotive Engineering* in northern Michigan.

A pump-less design which offers more than 30% lower spin losses than pump types, Actimax uses a multiplate wet clutch actuated by a servo motor to provide modulated variable torque split between the front and rear axles. Normally 60% rear-biased on the BMWs, when wheel slip is detected by the ABS/stability control, the system can react within .10 s to redistribute up to 100% of engine torque to the front or rear axle. The system can brake each wheel individually to help regain traction or directional stability.

An evolution of Actimax that will debut in 2016 on a front-drive-based AWD vehicle is Flex4, which adds a rapid-disconnecting mechanism on the PTU. Flex4 enables the traction-coupling clutch to be fully opened, disconnecting the drive axle from the driveshaft. Drag torque is claimed to be in the 1 N·m (.7 lb·ft) range, said Khatra, and the system is capable of providing a 4-7% fuel economy gain, depending on vehicle type. (See http://articles.sae.org/13615/).

Getting a grip on AWD efficiency

The next generation of axle-disconnect AWD systems will be simpler, lighter, more compact, and cost-effective, said Rob Genway-Haden of GKN.

ZF's ECOnnect is a variety of AWD driveline solutions with an available disconnect capability. The product range includes both single-clutch (shown) and twin-clutch RDMs. Designed for FWD-based AWD architectures, it is aimed at significantly reducing the fuel-efficiency delta between the 2WD base vehicle and the AWD version.

RDMs (rear-drive modules) are becoming more sophisticated in the latest AWD systems, as seen in the new ProActive RDM fitted to **Mercedes**' GLA, CLA, and A45 AMG utilities. Developed by Magna specifically for C-segment utilities, ProActive integrates an AWD coupling with the RDM for reduced weight by 10% (more than 2 kg/4.4 lb), the companies claim. The system features a common oil circuit to improve coupling functionality in extreme conditions while minimizing the overall package size. The design also eliminates bearings and seal rings to reduce internal drag by approximately 14%.

No 'one size fits all'

The crossover-utility market is driving demand for "smart" axle disconnects, experts said, after impacting the light truck segment—the **Ram** 1500 pickup features a front axle disconnect as part of its fuel-efficiency technology suite. Jeep's 2014 Cherokee, based on a FCA front-drive architecture instead of a traditional rear-drive configuration, offers rear-axle disengagement (via AAM driveline technology) when 4x4 capability is unnecessary. See June 2014 cover story: http://www.nxtbook.com/nxtbooks/sae/14AUTP06/index.php.

"In a perfect world you want to disconnect the PTU, the prop shaft, the RDM, and the half shafts, but to do that is going to be more costs and more weight. Some OE customers want no end-customer interaction while others want an AWD select function," observed Paul Olexa, Vice President of Sales and Marketing for Driveline of ZF North America, which supplies the Ram's set-up. His company has developed a portfolio of AWD disconnects, from relatively simple viscous-clutch-based types to electronically-controlled systems that disengage and engage in milliseconds.

"The market is really expanding and it's not one-size-fits-all," he noted. Reducing spin losses and overall internal friction was the design direction behind ZF's ECOnnect, a variety of AWD driveline solutions with an available disconnect capability. The product range, including both single- and twin-clutch RDMs, targets FWD-based AWD architectures and is aimed at significantly reducing the fuel-efficiency delta between the 2WD base vehicle and the AWD version. Compared to a conventional hang-on AWD system, the disconnect system therefore reduces the friction losses in the AWD driveline by up to 90% in the disconnected mode, ZF engineers claim.

Coupling and decoupling actions are accomplished using electro-mechanical or electro-magnetic actuators tuned for optimum balance between shifting speed and seamless operation. For details, see **SAE** Technical Paper 2013-01-0362, "AWD Disconnect Solutions, ZF ECOnnect," that covers specific design elements, performance and control, and test results.

"We've picked a lot of the low-hanging fruit with the base AWD technologies and now comes disconnect systems and, on some vehicles, electric rear axle drives which allow you to launch electrically and maybe recover some braking energy," Olexa said. ZF's electric rear-axle drive (e-RAD) currently under development is a stand-alone, designed to work with a conventional FWD powertrain. Olexa said some OE customers are looking for a conventional rear axle that offers some degree of electric assist.

Scaling for A and B segments

Great attention to detail in systems engineering is paramount to creating excellence in AWD systems, explained Ray Kuczera, Ph.D., VP of Engineering at GKN Driveline Americas. "Making sure the AWD system can communicate

Above: Schaeffler Group's new AWD disconnect unit uses a switchable bi-directional one-way clutch to significantly reduce space, mass, and cost. The self-energizing unit is hydraulically actuated but electro-mechanical actuation is also possible. In operation it enables the vehicle prop shaft to come to near zero speed, eliminating the losses in the bearings, seals, and fluid windage. It also enables seamless synchronization because there is no drop in synchronization torque between the synchronizing and locking phases as in a conventional synchronizer. Drag torque cannot allow the shaft speeds to come out of alignment before the clutch is locked.

Developed by Magna specifically for C-segment utilities and used on the new Mercedes GLA and CLA, the ProActive system integrates an AWD coupling with the RDM for a 10% weight reduction. The system features a common oil circuit to improve coupling functionality in extreme conditions while minimizing the overall package size. The design also eliminates bearings and seal rings to reduce internal drag by approximately 14%.

with the rest of the vehicle, how you control it and making sure it works with the ABS and traction control, and how you integrate the system, are critical. Also, how you tune the system to get specific brand DNA."

He cited GKN's new compact, disconnecting AWD system for A-, B-, and C-segment vehicles that is shared by two **FCA** platform mates—the 2015 **Fiat** 500X, marketed as a "soft-roader," and the 2015 Jeep Renegade that is "Trail Rated" by Chrysler and is said to be quite capable off road.

In the system, the PTU is linked to the vehicle's final-drive differential and contains a rapid-disconnect capability and a braking system to stop the AWD system upstream of the unit's hypoid gears. An electro-mechanically-actuated clutch located on the rear axle biases drive torque and disengages the AWD system downstream of the hypoid gears in low-load cruise conditions. Torque vectoring is used between the vehicle's rear wheels, torque-biasing handles front/rear axle distribution when AWD is engaged.

AWD reconnection can be established in 300 ms, according to company engineers. For more details see http://articles.sae.org/13610/

"How a disconnecting AWD is programmed, how it disconnects and reconnects AWD, and how often and how quickly it does it, that's where a lot of the development is taking place," said Genway-Haden. "It's very critical you shift out of AWD into 2WD so the driveline stops rotating as often as possible, and hold it there as long as possible until the driving environment dictates that AWD should be available—while doing it as imperceptibly to the driver as possible.

"That's a huge amount of work wherein taking the systems approach makes a vast difference," he said. ■

Ajit Khatra, Magna Powertrain's Manager of Vehicle Verification and Testing, expects his company's new Flex4 AWD disconnect system to deliver up to 7% fuel economy improvements depending on vehicle type. He's shown here during a 2014 winter test session in Michigan's Upper Peninsula. (Image by Lindsay Brooke)

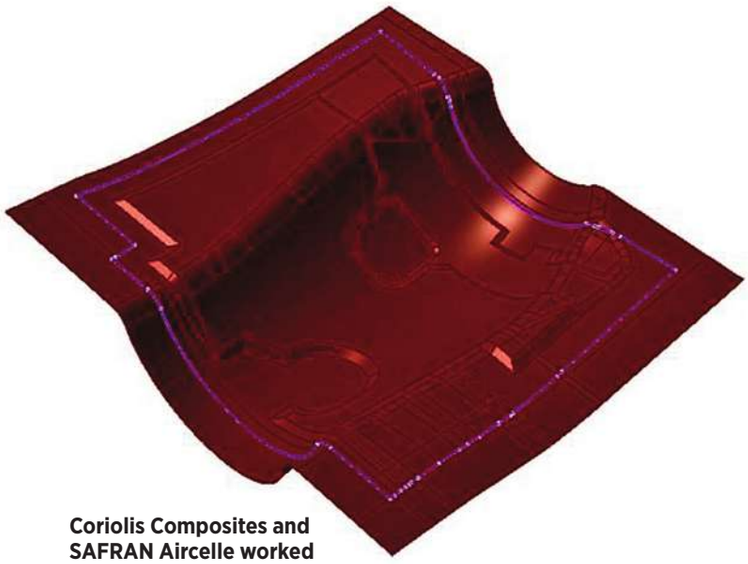
Composites design optimization for automated fiber placement

Coriolis Composites and SAFRAN Aircelle worked together on a thrust reverser component demonstrator made with carbon-fiber-reinforced plastic (CFRP) material and an AFP process.

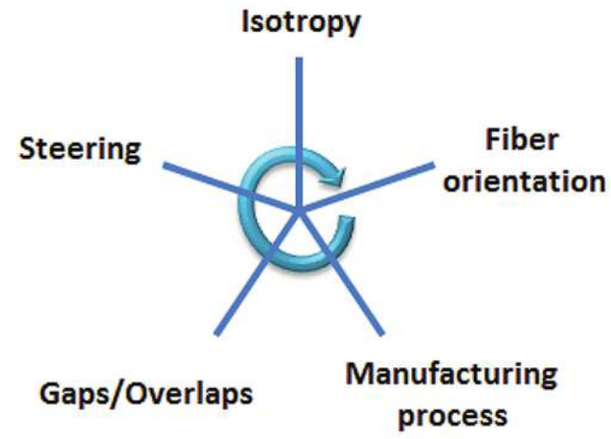
Complex composites structures are becoming more common, especially in aeronautics. Composites preforms can now be manufactured by automated processes, such as automated fiber placement (AFP) and automated tape laying (ATL), to achieve the expected production volumes.

The AFP process is the most interesting since it can address complex double-curvature layup surfaces with good productivity rates and low material scrap, according to **Coriolis Software**. The main advantages of this technology are that material can be steered to address the problem of curvature, and fiber angular deviation from the engineering rosette can be easily managed. This opens interesting possibilities to optimize the design of composites structures and to change the current traditional "black metal" approach of design offices.

But these benefits also induce new problems to solve in terms of potential manufacturing defects, such as wrinkles, bridging, gaps, and overlaps. The



Coriolis Composites and SAFRAN Aircelle worked together on the component, an inner fixed structure (IFS) made of two monolithic carbon skins and a core (above).



Major constraints for optimal design with AFP process.

offline programming system used to build the tape courses over the layup surface should be able to predict these defects but also help find an optimal draping strategy.

These systems should integrate all the programming features at the design stage, allowing the design engineers to make smart proposals to NC programmers, validated by stress analysis, and hence eliminating useless loops and trials.

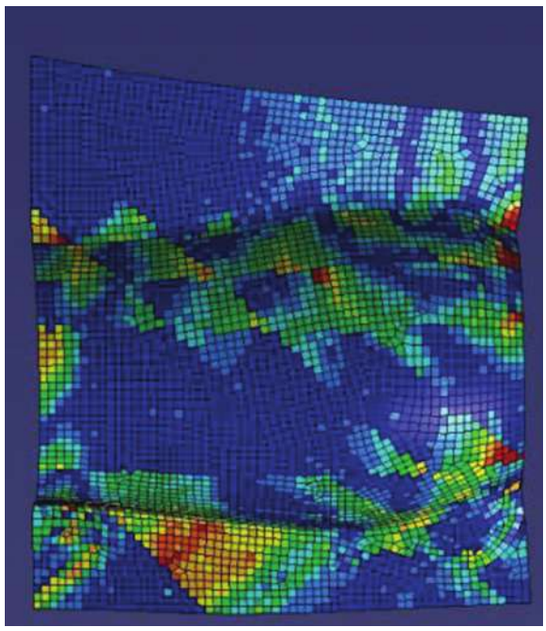
Researchers from Coriolis used an aerospace use case to illustrate the required software features for optimal fiber-placement programming. Through the collaborative research project "Defi Composite," **Coriolis Composites** and **SAFRAN Aircelle** worked together on a thrust reverser component demonstrator made with carbon-fiber-reinforced plastic (CFRP) material and an AFP process. This component is an inner fixed structure (IFS), made of two monolithic carbon skins and a core.

The goal of this project was to highlight the benefits of an AFP process compared to manual hand layup, in terms of layup quality and productivity rate.

Multiple constraints for optimal design

The most important thing to understand with AFP programming is that both engineering and manufacturing specifications need to be managed, and are often in contradiction. That's why the software system should be designed to address not only NC programmers, but also composites designers, project leaders, and stress engineers.

Five constraints are identified with a key role for optimal design with an automated manufacturing process: fiber orientation, isotropy, fiber steering radius, fiber gaps and overlaps, and the manufacturing process. Coriolis presents an implemented solution for each constraint.



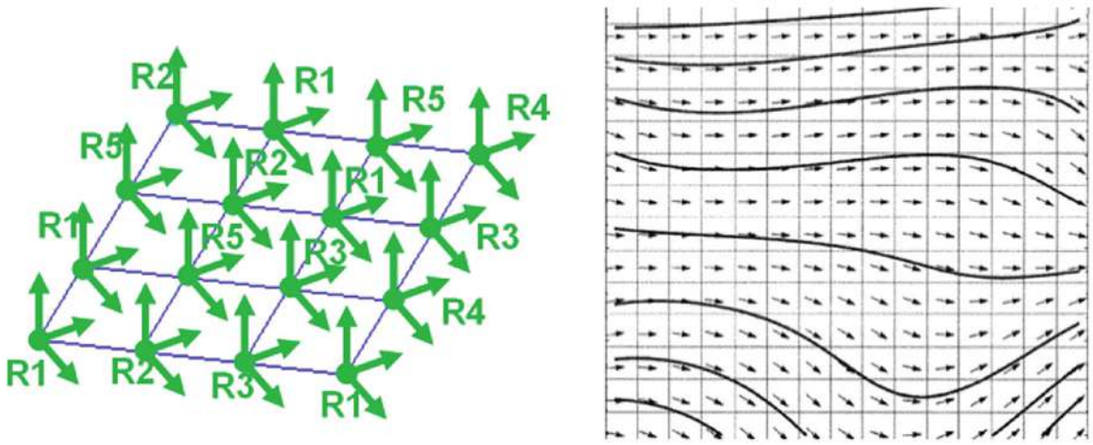
Example of isotropy image based on realistic composites shell properties exported from fiber-placement programming data (red areas: largest fiber deviation angles).

For example, the offline programming system offers the possibility to analyze isotropy, since the maximum fiber deviation constraint alone can be too restrictive. Isotropy is the measure of the relative fiber angle between two layers at a same measurement point, for example between a 0° and a 90° ply.

A specific development was done to export fiber angle deviation for each layer from the programming courses, in order for the stress engineer to validate fiber orientation and isotropy. This software add-on is integrated on top of the offline programming system to ease communication between designers and stress engineers.

The main steps for capturing the fiber deviation and isotropy for structural analysis are: 1.) Mapping of fiber

Composites design optimization for automated fiber placement



Example of a grid mesh and rosette axis vectors (left), and a resulting vector field with generated tape streamline paths (right).

centerlines on FE shell mesh, 2.) Core sampling at finite element centroid point, 3.) For each layer of the stacking sequence, get the closest fiber direction and evaluate angle deviation from the cartesian rosette, 4.) Writing of a composites shell property with "true" material angle, for each mesh element, and 5.) Factorization of stacking sequence using a custom angular tolerance, in order to minimize the number of composites properties.

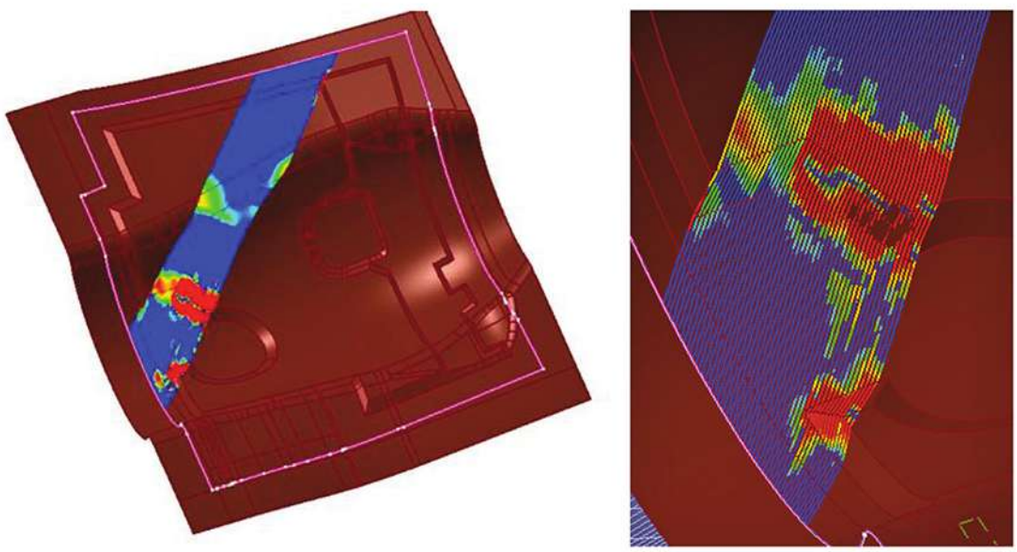
Concerning fiber steering radius, the constraint is mainly caused by fiber in-plane curvature and material width, and may lead to wrinkles and tow buckling. This kind of defect is not perfectly well understood in terms of direct impact on structural strength.

Fiber steering is very complicated to interpret, since it depends on other parameters such as material tackiness, compacting pressure of roller, layup velocity, heating power, and intermediate vacuum bagging. For this reason, fiber steering radius analysis at the design stage should always be correlated to real sample tests in order to get the empirical knock-down factors.

The software system is able to detect this problem at least through a geometrical analysis of the in-plane curvature of tow centerline curve, in order to highlight critical areas. The designer can also easily do "what if" scenarios with different material widths (1/4-in or 1/8-in) or types (thermoset, dry fiber).

Steering issues can be solved at the design stage by either using a geodesic path approach—for example, through a complex rosette transfer—or by locally decreasing the layup velocity. This can be achieved by defining a local "process contour" in the software system (also called manufacturing strategy), after identifying the highly steered areas over the surface, and then applying a lower nominal machine velocity.

Experimental trials showed that it can significantly improve the final layup quality.



Fiber steering radius analysis over honeycomb ramp edges.

Final layup of cover skin of IFS demonstrator using the Coriolis Composites AFP robot.

Automatic ply boundary splicing

To optimize the design for AFP, one solution is to split the ply boundary in several pieces, called sectors or regions. This task can be manually achieved, but it's time consuming, and more important, it will not be easy to obtain an optimal result.

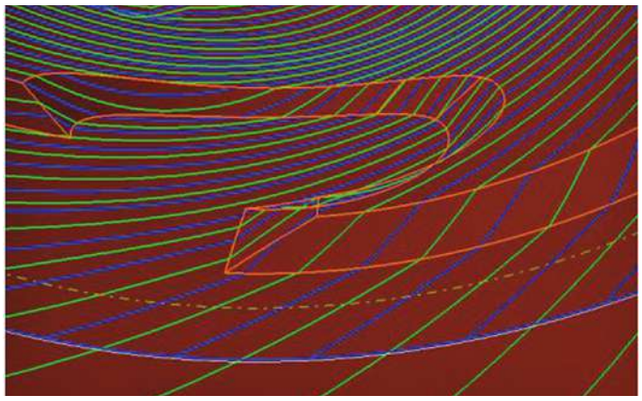
The optimal result of the problem is to minimize the number of sectors and tape courses within the ply, and to avoid too many material feeds and cuts (leading to slow layup velocity).

A specific software module was implemented in that way, to automate the sector and guide curves creation, starting from the following initial conditions: geometrical layup surface, engineering rosette axis, ply contour, initial seed-point, material width, maximum number of tows by course, maximal angular deviation, and minimum steering radius.

The system is based on an iterative algorithm, building a fixed angle path and parallels, and then cutting the ply boundary if the parallels present excessive angular deviation. The output result is a list of sectors, each made of a closed contour and one or several guide curves.

After many trials and experimental validations, the system was improved to integrate the following specifications:

- Avoid ply cuts and tow drop off located in a specified zone (example: stringer bonding area)
- Adjust the tape width (number of tows) if roller conformance is not compliant (excessive crush or fiber bridging defects)
- Minimize the gap between adjacent tape courses
- Management of sequence of several plies in the same layer (patch areas).



Ply automatic splicing result on IFS core skin. Sector closed contour with guide curves (tape course centerlines).

Compared to a traditional approach (ply with one single guide curve) or a manual ply sectors method, the automatic method proposal provides significant benefits. The major benefits include the programming time (limited required skills, possibility to manage iterative design loops) and the convergence to an optimal result, very difficult or impossible with other methods because of the large number of parameters and constraints.

A solution was successfully implemented on a complex aerospace case, with competitive results compared to a manual hand layup process in terms of structural strength, layup quality, and productivity rate. Improvements will be made for extending the automatic method to manage geodesic path as sector guide curve, and control the staggering distance of tow drop off areas. ■

This article is based on SAE International technical paper 2014-01-2261 by Yvan Blanchard of Coriolis Software.

Making **VIRTUAL VEHICLE DESIGN** a reality

A new virtual design approach for commercial vehicle concepts allows for purposeful design and integration of new concepts and technologies on the component level in an existing product portfolio, while not neglecting the need for standardization and modularity.

With products more and more diverse and growing vehicle portfolios on the market, variant management has become of enormous significance in coping with challenging cost and quality requirements. Modular systems and related methodologies are a common approach in many companies and currently are widely discussed in research. But the research on modularity and its management has not yet reached application-oriented maturity, and implementation in industry is rather fragmentary for different companies, industries, and products.

Commercial vehicles are high-variant products with comparatively small production volumes; therefore, a concept development phase focusing on variance becomes a major aspect in planning and determining standards, modularity, and commonality within the future product portfolio. Due to long product life cycles (typically 20 to 30 years), the basic architectures of commercial vehicles continuously undergo a small evolution and many technical changes and innovations have to be held available—in many cases triggered by changes in legislation. Therefore, both the careful planning of design interfaces and their management are important for successful use of modularity and commonality within the product ranage.

With comparatively low production volumes of approximately 100,000 vehicles per year and a large portfolio of configurable vehicles (about 1046 possibilities from a functional point of view), the vehicle design should be highly modular to cater to the breadth of the product portfolio with the existing R&D resources. In particular, the advantages of modularity in this industry are found in focusing design efforts on commonality (i.e., designing once, using multiple times) rather than in the economies of scale in production and purchasing, which are still low due to overall low production volumes. In addition to advantages in cost efficiency, quality can also be improved: Cross-product multiple use of standardized components and modules allows for more economical technical validation and facilitates concentration on a minimum of reference vehicles for testing.

For the past several years, **MAN Truck & Bus** AG and **Technische Universität München** have been cooperating as part of an application-oriented and industry-relevant research project, and their findings are presented here.

Obstacles to standardization

Commercial vehicles are characterized first and foremost by challenging requirements concerning manufacturing costs and durability, i.e., quality issues.

Against this background, manufacturers strive to combine improvements in cost efficiency and quality by means of implementing modularity and internal standardization in their development processes—coping with the market-related constraint of a required high-variant product portfolio.

The engineering design process is affected by four challenging aspects that complicate modularity and standardization objectives:

• The variant spectrum for commercial vehicles is comparatively high and results both from an OEM's strategic alignment and from an unavoidable high variety of customers' utilization scenarios and transportation tasks. Typically, vehicles are assembled to order, yet the design caters to a high degree of specialization in transporting specific goods.

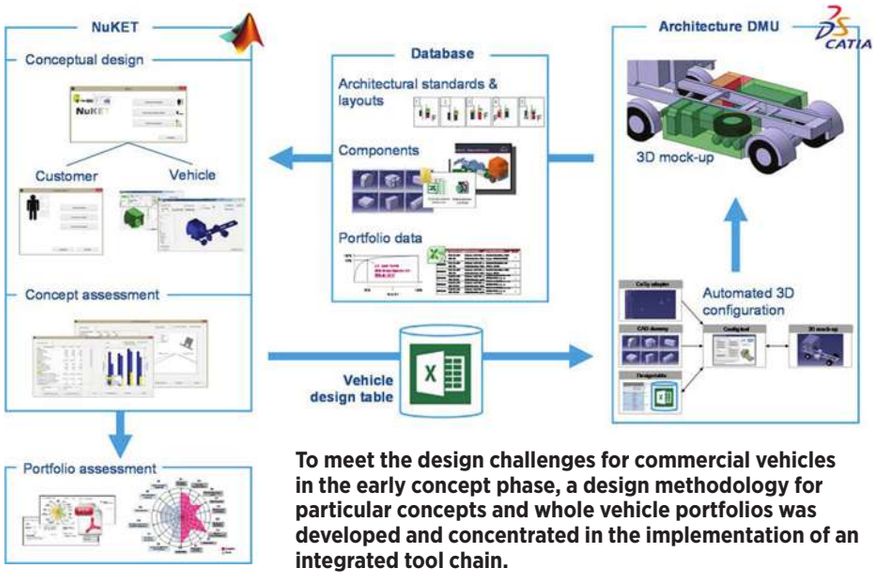
• The positioning and the available installation space for components are essential aspects. Customers' orders typically include several customization requests profoundly influencing the vehicle layout and asking for individual installation space for own components (e.g., toolboxes).

• Further adaptations are done by body manufacturers to finalize the vehicle beyond the OEM's area of influence (such as tippers, mixer trucks, etc.). To allow for optimal body mounting, the OEM has to make many interfaces available as optional adaptations.

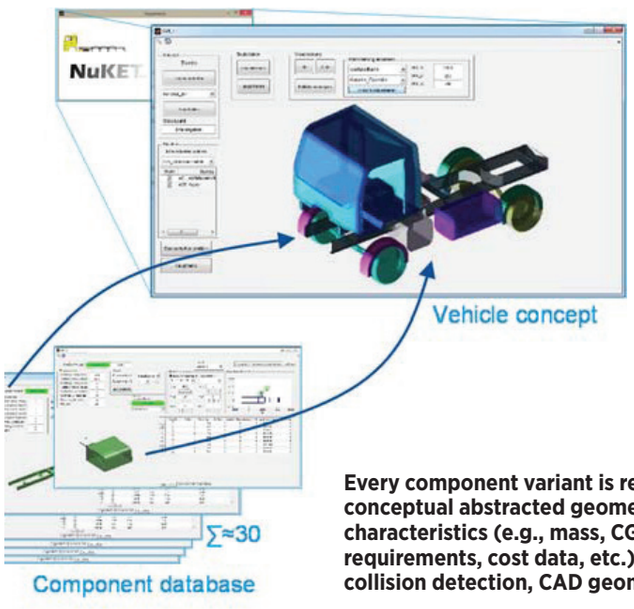
• All aforementioned aspects appear in combination with long life-cycle periods of 20-30 years, bringing substantial uncertainties regarding future changes—initiated on customer side or technologically or due to legislation.

These challenges result in high efforts to engineer and manage this variance with an unavoidable lack of transparency. With respect to the low sales volumes per vehicle variant, commercial vehicle portfolios are not upgraded or set up newly all at once, but evolve slowly over many decades. Thus, the modular kit is growing additively with little systematic forward planning. New customer

MAN Truck & Bus AG vehicles are built to afford a great deal of versatility. The MAN TGS (shown) can be configured as a two-, three-, or four-axle vehicle and in standard, medium, all-wheel-drive, and ultra-low heights.

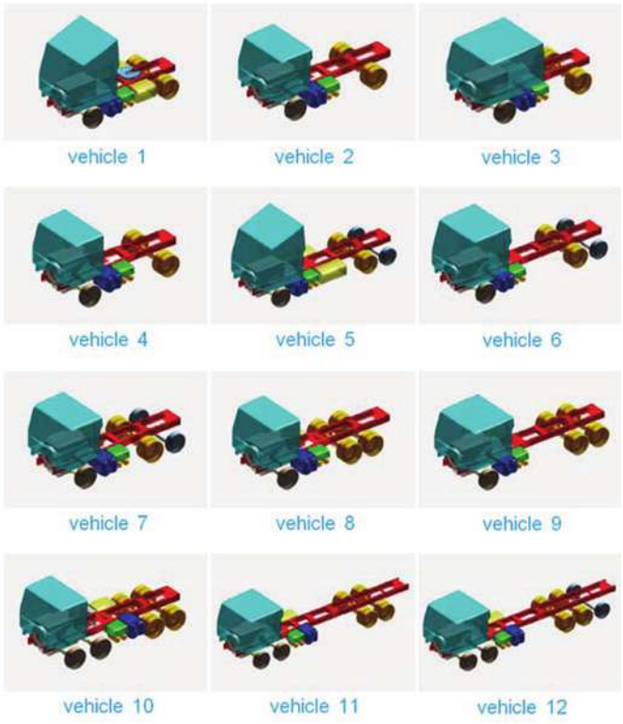


To meet the design challenges for commercial vehicles in the early concept phase, a design methodology for particular concepts and whole vehicle portfolios was developed and concentrated in the implementation of an integrated tool chain.

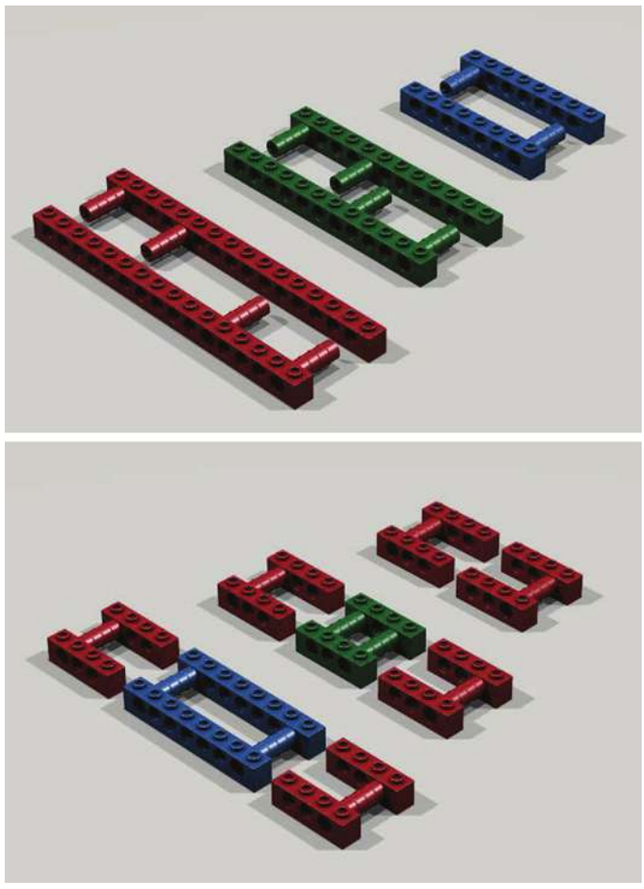


Every component variant is represented by a conceptual abstracted geometry and relevant characteristics (e.g., mass, CG, material, package requirements, cost data, etc.). For visualization and collision detection, CAD geometry is integrated.

Making **VIRTUAL VEHICLE DESIGN** a reality



Twelve vehicles were designed and optimized for the demands of 15 customer profiles. These profiles range from a standard tractor unit for a semi-trailer to a five-axle concrete pump for construction sites and an inner-city garbage truck.



Two technical solutions for a new truck frame were developed. Solution A (top, simplified and re-created with LEGO) consists of three half-frames whereas solution B (bottom) consists of an end module and two different middle modules for the creation of the three frames.

demands and vehicle configurations are made possible, corresponding to the customer order inflow. The component variants and especially their dependencies increase steadily, and as a result, changes evoke further subsequent changes. Efforts, costs, and even the exact portfolio penetration of changes can be hardly estimated. Hence, at MAN a significant percentage of productivity in engineering and construction is necessary for clarifying the particular variance context before realizing product changes.

Constructing concepts

To meet the design challenges mentioned, a design methodology for particular concepts and whole vehicle portfolios was developed and concentrated in the implementation of an integrated tool chain.

In the center of the methodology presented, an integrated virtual tool chain is established. It includes a mathematical design tool for vehicle concepts and associated customer profiles and operational scenarios, respectively (implemented in **MathWorks**' MATLAB environment). After linking vehicle concept and usage profile, essentially complete vehicle performance factors are calculated and referred to a customer-specific rating system (relevance and utility value of criteria). In the event of several vehicle concepts, there is a key performance indicator (KPI) analysis assessing the whole vehicle portfolio. Finally, every vehicle concept is converted automatically into an architecture digital mock-up (DMU). In the architecture DMU component integration, possible collision and potential standard packaging spaces, and vehicle layouts are investigated. Promising standardized layouts can then be set as compulsory for all subsequent vehicle concepts to be designed in NuKET (Nutzfahrzeug Konzept Entwicklungs Tool or commercial vehicle concept design tool) to enforce commonality and synergetic effects in development and production.

The design tool NuKET allows for developing vehicle concepts through accessing a database of 30 actual main components (e.g., fuel tank, cabin, etc.) with several corresponding component variants (e.g., 66 geometrical variants of fuel tanks—i.e., different material, length, and cross-section). Every component variant is represented by a conceptual abstracted geometry and relevant characteristics (e.g., mass, CG, material, package requirements, cost data, etc.). For visualization and collision detection, CAD geometry is integrated.

To gradually develop complete coherent vehicle concepts, main components can be manipulated as to their position (e.g., change of ladder frame side) and their

UC1 Key Performance Indicators				
	Exemplary KPI	Exemplary Value	Optimized KPI	Optimized Value
Variety of components	3.0833	8.3	2.0833	9.1 (+0.8)
Distance to customer ideal point	3.3547	4.0	3.4520	4.1 (+0.1)
Function ratio	8.0833	9.3	8.0833	9.3 (+/-0.0)
Degree of interdependence	0.9993	1.0	0.9844	1.1 (+0.1)
Variety of mounting positions	1.1081	9.9	1.2000	9.8 (-0.1)
Completeness of wheelbases	0.6800	7.1	0.7200	7.5 (+0.4)
Relative number of product variants	0.8000	8.1	0.8000	8.1 (+/-0.0)
Degree of standardization	0.3311	4.0	0.4900	5.4 (+1.4)
Distribution of quantities	0.6118	6.5	0.6820	7.1 (+0.6)
Range of product variants	2.1391	3.1	2.2302	3.2 (+0.1)
Relative diversity of product variants	3.5221	2.3	3.7186	2.4 (+0.1)
Variant flexibility	0.3243	1.2	0.4800	1.4 (+0.2)
Value intensity	0.2397	3.2	0.3904	4.5 (+1.3)
Repetition rate	1.0405	1.1	1.0796	1.2 (+0.1)
Reutilization ratio	3.5946	3.1	5.2800	4.5 (+1.4)
Average		4.8		5.3 (+0.5)

specific variant (e.g., fuel tank size). If required for challenging complete vehicle characteristics, design studies on the component level can also be conducted by adding new component variance with individual properties. One or several customer profiles can be assigned to every vehicle concept to analyze their degree of applicability.

Having linked a vehicle concept and a customer profile, the final assessment can be conducted. The vehicle concept is characterized by 35 basic complete vehicle characteristics (e.g., fuel efficiency, road wear factor, turn radius, etc.). Different alternative concepts can be evaluated in the light of a customer profile and compared regarding their applicability.

Test cases

The evaluation methodology and the evaluation tool for portfolios of heavy trucks have been tested in two demonstrative use cases (UC). Use case 1 focuses on the analysis and optimization of an exemplary vehicle portfolio. Use case 2 shows the possibilities of applying the evaluation methodology to support strategic decision making.

The main benefit of the portfolio analysis report is to show potential areas for portfolio optimization. To test this, a scenario of sample vehicles and customer profiles has been created in NuKET. Twelve vehicles have been designed and optimized for the demands of 15 customer profiles. These profiles range from a standard tractor unit for a semi-trailer to a five-axle concrete pump for construction sites and an inner-city garbage truck. They represent the significant variety of requirements commercial vehicle customers have (tank volume, ground clearance, wheelbase, cabin size, etc.).

Following the methodology, the portfolio is analyzed. KPIs are being computed and then related to one data scale. A portfolio analysis report with all information is generated automatically.

The following weaknesses could be identified in the detail analysis:

- There is a big variety in the components frame, cabin, fuel tank
- There is a big gap between the wheelbases 3600 and 4400 mm (141.7 and 173.2 in)
- The quantities of the components cabin, frame, and engine are distributed inconveniently
- The value intensity of the components frame, cabin, and front axle is suboptimal
- Vehicles 2 and 3 are almost identical in terms of customer relevant characteristics.

For the optimization of the portfolio, the following measures are being taken:

- Reduction of cabin variants—Creating a cabin that fits both off-road and on-road chassis, reducing the total number of available cabin sizes
- Reduction of frame variants—Reducing the total number of available frame lengths, merging frames of similar lengths
- Optimization of fuel tank variants—Introducing a system of new standard tank layouts, based on the customer requirements
- Optimization of front and rear axle variants—Changing the wheel formula for two “exotic” variants and thereby

Key Performance Indicators for Solutions A and B		
	Value for Solution A	Value for Solution B
Variety of components	1.0	7.8
Function ratio	10.0	10.0
Degree of interdependence	10.0	10.0
Variety of mounting positions	5.5	8.5
Degree of standardization	7.0	9.0
Distribution of quantities	1.9	5.8
Variant flexibility	4.0	4.0
Value intensity	4.0	7.5
Repetition rate	4.0	2.0
Reutilization ratio	1.0	4.0
Average	4.8	6.9

reducing the number of combinations needed.

These measures are being carefully carried out with the portfolio development tool NuKET. The portfolio analysis report shows exactly which component variants to address and which component variants should be left unchanged.

The results of four optimization loops are showing relevant improvements in the configured vehicle portfolio. The values of almost all KPIs could be raised. Especially the degree of standardization, the variety of components, the reutilization ratio, and the value intensity could be adjusted. The modular kit of the portfolio became more flexible and cost effective, raising the quantities of most components and distributing them more efficiently. The customer-relevant characteristics of the portfolio (range of product variants, relative diversity of product variants, etc.) did not suffer from these optimization measures and could even have been slightly improved. The optimization measures have affected the variety of mounting positions in a negative way (in some cases, two or three component variants have been replaced by one component variant in two or three mounting positions). It is the only KPI with decreased value.

For UC2, a (generic) use case was created to show the use of the evaluation methodology in the support of strategical decision. Two technical solutions for a new truck frame have been developed. Both solutions consist of three components and are (hypothetically) identical in terms of part costs per frame and customer-relevant characteristics (e.g., stiffness of the structure, weight, etc.). Solution A consists of three half-frames whereas solution B consists of an end module and two different middle modules for the creation of the three frames.

The project leader has to decide which solution to take into the detailed design phase for series production. A portfolio analysis for the modular design of the two solutions was conducted.

Solution B was found to be much more efficient and flexible than solution A. The value intensity and the reutilization rate as well as the degree of standardization are significantly higher with this solution. It makes better use of the parts and will be more adaptable in case of changed requirements. The quantities of the components are distributed more conveniently. This will increase quality and lower the production costs in the long run. The only advantage of solution A is the high repetition rate. All components are used twice in every frame, which is going to lower the price per part.

Striking a balance

The virtual tool chain presented including concept design (NuKET) and 3-D layout planning (architecture digital mock-up) provides a valuable contribution already in the early concept phase by allowing for flexible and performant concept studies coping with reduced product knowledge according to the early phase.

Since the impact of singular vehicle concepts on the overall modular kit of components can be analyzed only retrospectively in the face of multiple vehicle concepts—i.e., having an entire vehicle portfolio—a KPI-based assessment metric has been developed. An aggregated KPI abstract and an automatically generated more detailed key figure report allows for identifying vehicle concepts at low degree of standardization within the portfolio (e.g., utilizing exclusively special components with low sales volume). To improve the overall standardization within the portfolio (triggered by cost and quality requirements on a competitive market environment), these vehicle concepts are revised. Finally, an optimal marketable vehicle portfolio can be generated by balancing between dedicated vehicles with best customer-relevant characteristics and standardized vehicles.

Having already shown promising results in first industrial case studies, the methodology presented is designated to be integrated in the product development process and the associated tool chain to be successively industrialized in extracts. ■

This article is based on SAE International technical paper 2014-01-2415 by Armin Förg, Moritz Wolter, and Markus Lienkamp of Technische Universität München, and Matthias Kreimeyer of MAN Truck & Bus AG.

Mercedes-Benz debuts 'car of the future' at CES

Designed around the future luxuries of space, time, and privacy, the **Mercedes-Benz** F 015 "Luxury in Motion" concept car had its world premiere Monday night at the 2015 International CES.

"The idea is about designing the entire car around the advantages of autonomous driving, while making use of the added room you have in an electric car without the engine and transmission," said Dr. Dieter Zetsche, Chairman of the Board of Management of **Daimler** AG and Head of Mercedes-Benz Cars.

Providing the maximum possible space for the passengers was achieved with a large wheelbase of 3610 mm (142 in) and short overhangs. Length, width, and height are deemed "unusual proportions" by Mercedes-Benz with 5220, 2018, and 1524 mm (205.5, 79.4, and 60.0 in).

"We were able to create the monolithic appearance of the exterior—as if hewn from a single piece—in particular through doing without conventional windshield and window design," said Gorden Wagener, Vice President Design, Daimler AG. "The flush-fitting side windows have an almost mirror-like appearance thanks to their extremely finely patterned surface. As they are close in color to the cool, technical appearance of the alubeam paint finish of the vehicle body, the transition from the windows to the bodywork is almost imperceptible. In addition, there are neither exterior mirrors nor visible A-, B-, or C-pillars to interfere with the overall impression of a sensual, object-like sculpture."

The interior features a variable seating system, with four rotating lounge chairs that allow a face-to-face seat configuration. Vehicle windows can be used as screens, with six display screens integrated into the instrument panel and the rear and side panels. Passengers can interact with the vehicle through gestures, eye-tracking, or by touching the screens. A free-floating control unit enables any of the four passengers to take control of the vehicle.

To ease ingress and egress, the electrically powered seats swing outwards by 30° as soon as the doors are opened. With rear-hinged saloon doors, the front and rear doors can be opened and closed independently of one another.

"This is the Mercedes-Benz vision of the next automobile revolution," said Dr. Dieter Zetsche, Chairman of the Board of Management of Daimler AG and Head of Mercedes-Benz Cars. "Cars will be re-thought in terms of shape and design, in terms of outside interaction, and in terms of inside interaction." (Matthew Monaghan)

"In the interior we focused on comfort, an extraordinary sense of space, and the luxurious lounge character," Wagener said. "The displays allowing nonstop, all-round information and interaction link the analog and digital worlds together."

The high-resolution screens in the

The interior features six display screens integrated into the instrument panel and the rear and side panels.

The F 015 has large communication displays at the front and rear with LED panels. By changing the color of the lights, the vehicle indicates what driving mode it is currently in: blue for autonomous and white for manual.

side windows can be used to display personal information for each passenger, including Web browsing, contacts, email, and video conferencing.

The B-pillar has been eliminated thanks to a specially structured body. A sturdy interconnected system with mechanical locking elements ensures safety standards are met. The resulting composite load path allows a high amount of energy to be absorbed in a frontal or side impact with minimal intrusion into the passenger compartment.

New materials and structures were used to develop the Smart Body Structure of the F 015. With the strategic use of carbon-fiber-reinforced plastic (CFRP), aluminum, and high-strength steels, the bodyshell was able to achieve a 40% weight reduction, compared with today's production vehicles.

Steel side members have been replaced in favor of plate-shaped multi-chamber sections made from CFRP composite. CFRP is also used for the pressurized hydrogen tank system's cylinders and mounting system.

Large LED light modules are positioned at the front and rear, which provide a range of different lighting functions. Communicating with the outside world by means of the LED fields, the lights show if the vehicle is being driven autonomously (blue) or is controlled manually (white). Road safety is also increased via a unique pedestrian communication system.

"Should a pedestrian wish to cross the road, for instance, the F 015 halts and scans its surroundings to check whether it is safe to do so," said Prof. Dr. Herbert Kohler, Head of Corporate Research & Sustainability and Chief Environmental Officer for Daimler AG. "If it is, the car uses a high-precision laser system to project a virtual crosswalk onto the road surface and additionally lets the pedestrian know it is clear to cross with an audible 'Please go ahead' prompt."

The F 015 was designed to allow the integration of an electric drive system with a fuel cell. The electric hybrid system has a total range of 1100 km (684 mi), including around 200 km (124 mi) of battery-powered driving and around 900 km (559 mi) on the electricity from the fuel cell.

The fuel cell stack delivers the traction current for two electric motors, each with an output of 100 kW. The electrical drive system generates a total peak power output of 200 kW (272 hp) and maximum torque of 200 N·m (148 lb·ft) per motor is available instantly. The F 015 is said to go from 0 to 100 km/h (0 to 62 mph) in 6.7 s with a governed top speed of 200 km/h (124 mph).

Matthew Monaghan

Komatsu America puts the HM300-5 articulated dump truck out there

Komatsu America Corp. first showed off its HM300-5 articulated dump truck at ConEXPO in Las Vegas last year.

Featuring a net 324-hp (242-kW) diesel engine, the HM300-5 is powered by a Komatsu SAA6D125E-7 engine that is **EPA** Tier 4 Final emissions certified. Komatsu's Tier 4 Final engines are based on what it calls "the solid foundation inaugurated in 1996 with the introduction of Komatsu's Tier 1 engines."

With a 30.9-ton (28-t) payload and a gross vehicle weight of 117,892 lb (53,475 kg), the HM300-5 maintains the productivity and performance of the previous model, and offers improved fuel efficiency.

Through what Komatsu describes as "body design optimization," the HM300-5 has increased body capacity and payload. The low 9'2" (2820-mm) loading height easily matches with 30- to 60-ton (27- to 54-t) hydraulic excavators or 5- to 7.5-yd^3 (3.8- to 5.7-m^3) wheel loaders. Additionally, the two single-staged body lift cylinders provide a 70° dump angle. Selectable working modes allow the operator to choose between Economy and Power modes to tailor machine performance to the application or work conditions.

The HM300-5 features the Komatsu Traction Control System (K-TCS) that automatically provides optimum traction when operating in soft ground conditions. As ground conditions worsen and tire slippage is detected by the speed sensors located on four wheels, automatic application of the inter-axle lock occurs. If tire slippage continues to be detected, then four independent brakes can be applied to slipping wheels to regain traction.

The HM300-5 is also offered with K-ATOMiCS (Komatsu Advanced Transmission with Optimum Modulation Control System). K-ATOMiCS offers a six-speed, fully-automatic transmission that uses an advanced electronic system to eliminate shift shock and torque cut-off to improve operator and engine effi-

Featuring a net 324-hp (242-kW) diesel engine, the HM300-5 is powered by a Komatsu SAA6D125E-7 engine that is EPA Tier 4 Final emissions certified.

ciency. It automatically selects the most suitable gear based on vehicle speed, engine rpm, and the shift position chosen. This results in powerful acceleration, smooth down-shifting, and synchronized engine speed when climbing slopes. This ultimately minimizes operator fatigue, keeps the load in the body, and increases productivity.

A large automatic retarder allows the operator to select the optimum operating speed on downhill travel and fully loaded hauls, eliminating acceleration generated by the grade of the slope.

An integrated payload meter (PLM) is now standard on the HM300-5. The PLM displays the loaded material weight on the 7-in high-resolution LCD monitor for the truck operator as well as indicates payload information to the loader operator via external display lamps. PLM data is also transferred via KOMTRAX, Komatsu's standard telematics system, and can be accessed by Web.

By integrating selective catalyst reduction, the Tier 4 Final engine further reduces NOx emissions using AdBlue/DEF. The engine uses an electronic control system to manage the airflow rate, fuel injection, combustion parameters, and aftertreatment functions to optimize performance, reduce emissions, and provide advanced diagnostic capability. The result is lower fuel consumption with no loss of performance, says Komatsu, which continues to use a Komatsu variable geometry turbocharger and an exhaust gas recirculation valve for more precise temperature and air management control as well as longer component life.

For product reliability and durability in demanding conditions, Komatsu developed the entire system, including the control software that is critical to the effective operation of the aftertreatment system. This control system is also integrated into the machine's on-board diagnostics systems and KOMTRAX.

The large cab of the HM300-5 provides a comfortable and quiet work environment. The ROPS/FOPS Level-2 certified cab has a newly designed rounded front dash panel with easy-to-reach switches. The center mounted high back, heated air ride seat with three-point seatbelt provides the operator with increased visibility during operation. The dashboard and front console provide easy access to all machine controls as well as visibility to the monitor panel. An auxiliary input has also been added to connect a smart phone or other device along with two 12-volt ports that have also been incorporated into the cab.

The high-resolution 7-in LCD monitor offers enhanced capabilities and displays information in 25 languages for global support. Through the monitor, the operator can easily modify settings for items such as the Auto Idle Shutdown or the auto-reversing fan, check operational records, such as driving history or fuel consumption, monitor the KDPF, or check how much time is required before the next maintenance interval. The monitor also provides the operator with the option of using the ECO guidance function, which will provide operational tips to reduce fuel consumption. A rear view monitor system with a separate 7-in LCD monitor is standard with every machine and is mounted on the right hand side of the console for operator convenience.

The HM300-5 provides easier service access in order to reduce costly downtime. The new truck has a light-weight fiberglass engine hood for easy access, increased cooling capacity, and two standard hydraulically driven auto-reversing fans to help keep the radiator and charge air cooler clean. The cab tilts rearward for easy access to the transmission and an electrically powered tilt function is now standard on the HM300-5.

The machine is equipped with the exclusive Komatsu EMMS (Equipment Management Monitoring System), which has enhanced diagnostic features that give the operator and technicians greater monitoring and troubleshooting capabilities. EMMS also continuously monitors all critical systems, preventative maintenance, and provides trouble-shooting assistance to minimize diagnosis and repair time.

Jean L. Broge

Toro launches new riding trencher

The **Toro** Co. says it designed its all-new RT1200 riding trencher with versatility and productivity in mind, particularly for utility contractors.

Built on a tool carrier chassis, its design allows contractors to select from tracks or tires and a variety of attachments, including a backhoe, six-way backfill blade, rocksaw, vibratory plow, reel carrier, and the Toro-exclusive HD (heavy-duty) trencher drive.

The Toro HD trencher drive consists of three major components—a flywheel, torsion shaft, and planetary gearset. The flywheel stores inertial energy, ensures efficient hydraulic system operation, and keeps the chain consistently running in tough digging conditions. The torsion shaft absorbs shock loads, and the planetary gearset multiplies the hydrostatic motor torque for added digging power. Toro says the HD trencher drive technology ensures consistent, powerful trenching performance in demanding digging conditions.

When it comes to plowing, the RT1200's P105 vibratory plow features plow-blade attitude adjustment, as well as plow steer and swing of up to 30° to maintain plowing accuracy and provide enhanced maneuverability.

According to Josh Beddow, Marketing Manager for Toro's underground utility equipment line, the RT1200 "is an operator-focused machine" with an open-design operator platform, easily accessible controls mounted to the arm rests, multi-adjustable high-back suspension seat, and large digital display.

Its **Cummins** 4.5-L, 121-hp (90-kW) engine and 48-gal fuel tank provide high output with minimal downtime. A standard tilt frame allows the operator to tilt the machine at variable degrees to maintain trench angle, while optional load control allows the operator to set the percentage of engine output dedicated to the ground drive to ensure the performance of the digging implement is maintained.

Jean L. Broge

The Toro HD trencher drive for the RT1200 consists of three major components—a flywheel, torsion shaft, and planetary gearset. The flywheel stores inertial energy, ensures efficient hydraulic system operation, and keeps the chain consistently running in tough digging conditions.

An "operator-focused machine," the RT1200 has open-design operator platform, easily accessible controls mounted to the arm rests, multi-adjustable high-back suspension seat, and large digital display.

First seen via a sneak peek at 2013 ICUEE, Toro's RT1200 riding trencher has been officially launched.

Built on a tool carrier chassis, the RT1200's design allows contractors to select from tracks or tires and a variety of attachments.

Attachments for the machine include a backhoe, six-way backfill blade, rocksaw, vibratory plow, reel carrier and the Toro-exclusive HD trencher drive.

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Q&A

"As long as safety and ecology remain in focus, automotive will be a continuous driver of [steel] innovation," said Greg Ludkovsky, Vice President of Global R&D, ArcelorMittal.

Lightweighting, safety drive steel development at ArcelorMittal

The steel industry is constantly innovating to develop new solutions that satisfy customers in a range of industries, the automotive industry included. Stricter fuel-economy and safety regulations challenge automakers to cut weight yet improve safety—which in turn challenges materials suppliers to come up with the technologies that enable such seemingly contradictory goals to be met. **ArcelorMittal** is among the companies pushing the boundaries of materials advancements. For the NAFTA region, the supplier expects orders for its advanced high-strength steels (AHSS), including press-hardenable steels, to rise from 20% of total automotive steel orders today to 35% in 2019. At any one time, up to 80 new steel grades are under development at ArcelorMittal. The person responsible for these advanced-development activities is Greg Ludkovsky, Vice President of Global R&D. Ludkovsky, who oversees 1300 full-time researchers at 11 research centers around the world, spoke with *Automotive Engineering* editor Ryan Gehm this past fall at the AM/NS Calvert plant in Alabama, which the company touts as "the world's most advanced steel finishing facility."

Could you talk about the significance of this Calvert plant and how it serves your purposes as a researcher?
Well, a lot of properties can be created in the hot strip mill based on the thermo-mechanical profile of what steel undergoes as it travels from the furnace all the way to the coiler. The greater flexibility you have in terms of reduction, in terms of temperature distribution, in terms of cooling rates, in terms of ability to create variable profiles in cooling, the more your ability to create unique properties. This mill is state of the art in respect to what you can do there. It's a very powerful mill, so you can take very heavy reductions—the heavier the reduction, the more you refine the microstructure, and the more you refine the microstructure, the better the hot roll properties. [The mill also] has a very long and very flexible cooling system on the run-out table—the distance between the last finishing stand of the cold mill, the hot strip mill, and the coiler. So when the steel travels in this distance, it changes phases, it changes grain size, [and] many other phenomena are taking place. You can have precipitation of certain elements that further strengthen the material. The fact that you have this unique flexibility allows you to do much more complex thermo-mechanical treatment, and therefore achieve a great deal of property improvement, for both the hot-rolled product and then ultimately cascading to the final product. That is the key advantage of this mill...For me as a researcher, the crown jewel is the hot strip mill.

Your R&D department serves many different markets. Which one's at the forefront of steel technology and provides the most challenges?
Automotive is definitely the most challenging. As long as safety and ecology remain in focus, automotive will be a continuous driver of innovation. But the market which is evolving and I believe will see a lot of interesting new developments is the energy market, because the sources of sweet oil [low level of sulfur] are getting depleted, so more and more we are dealing with sour oils. And more and more oil is coming from areas of extreme temperature, so the requirements in terms of performance of the material are increasing substantially. [In addition], we will be talking about carrying huge amounts of gases, for example, CO_2, shale gas, compressed gases, so there's new developments in...energy products. But I would say in terms of commitment, where the market's at right now, [the one that] gets the highest level of attention, it would be automotive.

What is the connection between your electrical engineering R&D and its application in EVs?
All the electricity that the battery will supply will be spent on two things: the positive one is propulsion—you'll be actually moving your vehicle; the other one is waste, electrical losses, manifested in the heat that will be generated in all of these motors...So what you do is develop very unique steels that go into the motors that decrease the amount of heat losses. We're in the forefront of these developments as well. And by the way, because these motors are very heavy, we can provide the product which gives what they require in terms of torque, and at the same time, very low losses. We are achieving both things: we're decreasing weight [and] we are letting—for the same battery with high efficient motors—the car run longer between charges. This is for purely electrical vehicles and for hybrids, so we're developing the steels for manufacturers in both [segments].

Blake Zuidema, Director of Automotive Product Applications, said that ArcelorMittal will have solutions should Ford decide to come back to steel for the F-150. What are those solutions?
In essence what Blake demonstrated in his presentation [on the S-in-motion steel pickup study] is the fact that we were able to take 174 kg (384 lb) out of a current [2014] pickup truck [using currently available AHSSs and press-hardenable steel grades such as Usibor 1500 and Ductibor 500]; we reduced by 23% the weight of the cab, box, tailgate, frame, etc., and with new steels [that are in the final stages of development] it'll be 26%. Our calculations show that with this combination of our new steels and our design solution, it's possible to reach 2025 targets.

Ryan Gehm

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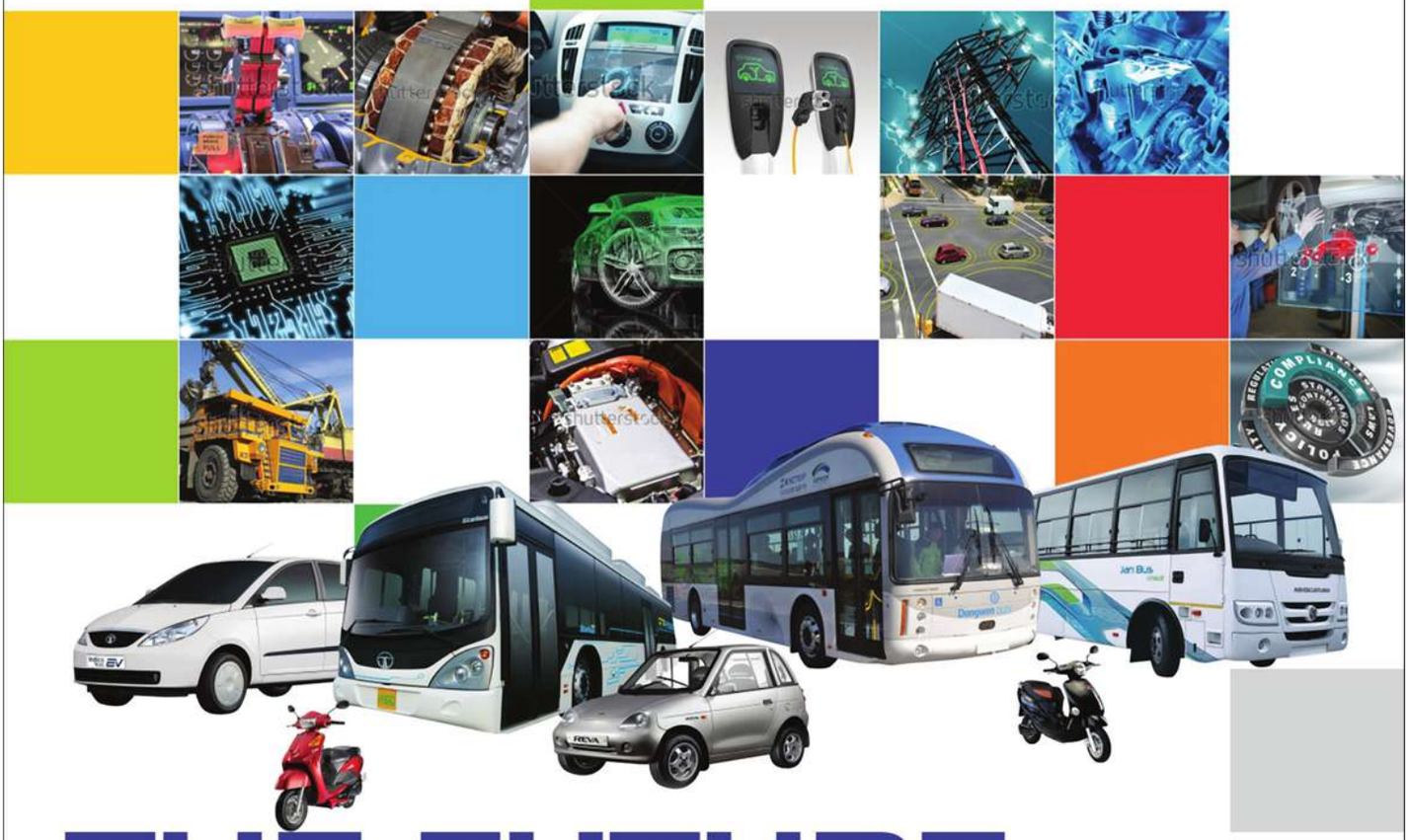

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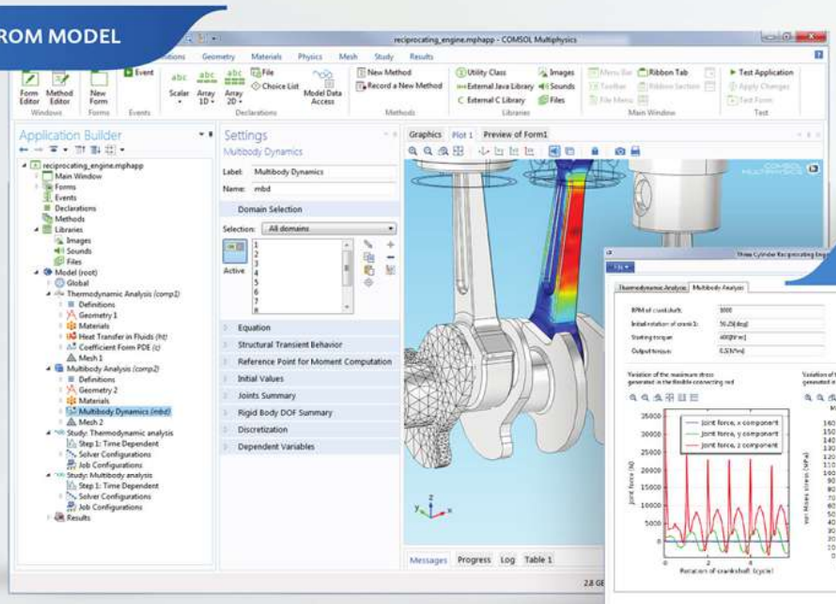

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