The Deep Orange 3 concept vehicle, developed and engineered by students from Clemson University and the Art Center College of Design, was unveiled at the Center for Automotive Research Management Briefing Seminars in Michigan.

Simulation Tools: Driving the Future of Design

The Clemson University Deep Orange 3 program introduced future engineers to analysis software, enabling them to develop a novel sports car concept architecture.

By Dr. Paul Venhovens

What does it take to develop a fully functional, hybrid mainstream sports car concept targeted towards Generation Y (Gen Y) consumers? Just ask the graduate-level students of the Clemson University "Deep Orange 3" program. They – along with a multi-disciplinary team of faculty and industry partners – worked to build such a prototype vehicle in just two years.

The Deep Orange 3 team harnessed the talents of graduate students in the disciplines of systems integration, automotive manufacturing, product development and design, and vehicle electronics to determine vehicle specs and branding fit for potential Gen Y consumers. As part of the program, the team collaborated on creating unique powertrain and seating concepts. It also explored the application of new technology to the automotive industry – Industrial Origami's patented Folded Metal Technology (FMT) – to develop the body-in-white (BIW) concept.

To meet the necessary performance requirements for the BIW's underlying structure, the Deep Orange 3 program partnered with Altair. The company's HyperWorks® suite helped team members to balance design requirements for BIW stiffness and strength.

The Next BIG Thing

Mazda North American Operations served as the primary industry sponsor of the Deep Orange 3 program while the Art Center College of Design, Pasadena, CA, was the design partner. Mazda asked the students to develop a vehicle for their own generation – a car recognizable as a Mazda that they would want to buy after graduation.

The Deep Orange 3 team named its overall vehicle concept NBT, for the Next BIG Thing. Since Mazda did not provide any specs for the concept car, the students started with market research and a blank sheet, identifying key specs as well as other elements of a new vehicle campaign such as target customers, key selling propositions and branding.

The team derived its concept for the powertrain based on extensive analyses of the Gen Y market. Data revealed that Gen Y was willing to invest in sustainable powertrain technologies and had an interest in all-wheel-drive.

From these findings, the team converged on a unique twin engine hybrid powertrain that automatically chooses front-, rear- or all-wheel-drive. Survey data also indicated that a significant portion of the social-savvy Gen Y would prefer a vehicle with five or more seating positions. The six-seat interior concept was proposed to accommodate a two-row, 3+3 seating configuration.

In the spirit of exploring new technology, faculty invited the team to apply FMT in the BIW concept. FMT allows the implementation of lighter gauge material folded into complex, innovative, high load-bearing structures that are formed with simple, low-cost fixtures at the point of assembly. The major advantage of FMT technology is that it avoids the significant capital investments in conventional tooling (several hundred million dollars) to form sheet metal vehicle components – potentially ideal for prototype development and niche, low-volume vehicle platforms. While FMT previously has been applied in the appliance industry, its general use in the automotive industry has been nonexistent.

Harnessing Disruptive Technology

Developing the topology and folding pattern geometry to meet the BIW functional aspects required an intensive collaboration among design students. And, as the project progressed, the Deep Orange 3 team discovered that folding an origami structure was no trivial task. For example, students worked to create folding pattern geometry as large as possible as well as to figure out the optimal way to fold it. They also investigated ways to nest parts to minimize material waste. Staff from Industrial Origami trained students to use the technology and understand its general features.

A cardboard mock-up was employed to demonstrate the feasibility of the FMT in highly loaded structural areas. Based on the results of the mock-up studies, students applied FMT to the front crush structure, the passenger compartment floor area and the rear crush structure.

The students started by building CAD models of the BIW design. Next, the team needed to determine the functional aspects of the design to achieve established targets. Altair's HyperWorks suite played the key role in these efforts.

Students imported CAD models into HyperMesh®. The FMT structural parts and tubular space frame components were modeled using 2D shell elements. Thicker-gauge BIW components – representing crucial design areas where the front subframe mounts to the body structure – were meshed with 3D hexagonal elements.

The team then conducted a series of in-depth finite-element

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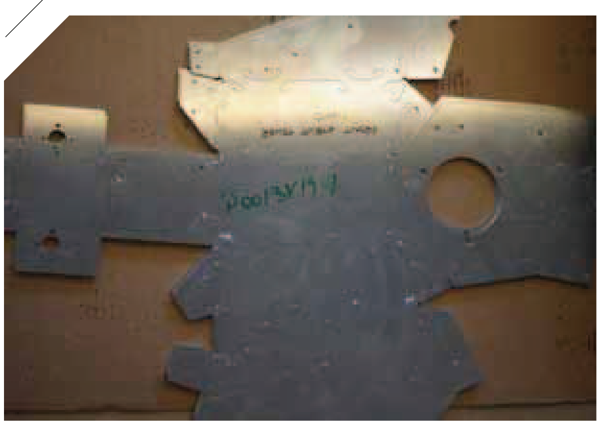
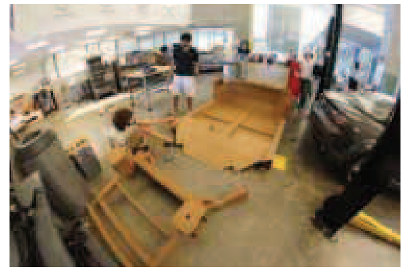


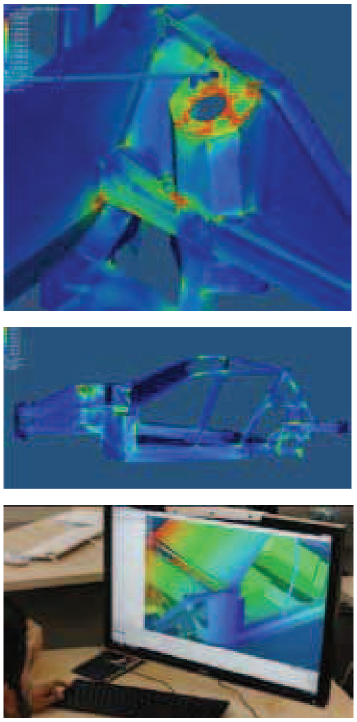
The Deep Orange 3 team worked hard to create folding pattern geometries as large as possible, the optimal way to fold them, and ways to nest parts to minimize material waste.

Team members of the Deep Orange 3 program work to transform concepts into reality.



analyses (FEA) covering torsional and bending stiffness, natural frequency and dynamic pot-hole and bump loads. The initial designs did not fulfill the structural performance of the vehicle in terms of bending and torsional stiffness. As a result, students performed multiple iterations, changing the models' topology, remeshing, then performing quick analysis studies using HyperWorks – engineering tasks reflective of what transpires in the automotive industry every day.

When the team converged on its final solution, the simulation results showed that the BIW design met the program requirements for body stiffness. What's more, FEA of the front subframe – applying dynamic loads from acceleration, braking and cornering maneuvers – demonstrated that "stress allowables" in strength-critical areas were also met.



Moving on to Manufacturing

After results from the simulations showed that the BIW structure met or exceeded strength and stiffness requirements, the team members performed the construction on the vehicle. The FMT body components for the front substructure, floor and rear substructure were bent to shape using the experience gained from forming the cardboard mark-up.

The FMT BIW design was completed using aluminum material along with structural adhesives and a limited number of rivets to join components. Seats for the 3+3, two-row passenger compartment were installed, along with the instrument panel, steering wheel and driver powertrain controls.

The front subframe, a simulation-driven design and critical assembly to support the front engine powertrain, was mounted to the forward body structure. The powertrain was then installed.

Simulation tools from Altair aided students in evaluating shock tower stresses and torsional stiffnesses (top) of their concept car (bottom).

Diving into Deep Orange 3

The Deep Orange 3 program, part of the Clemson University International Center for Automotive Research (CU-ICAR), runs the course of two academic years in parallel with Clemson's two-year masters program in automotive engineering. It provides students with experience in financial and market analysis, vehicle design, development, prototyping and production planning while giving them an opportunity to work with automotive industry partners to develop ideas.

To date:

- 189 students are currently enrolled
- 91% of students are gainfully employed in the automotive industry
- 44% of alumni are employed in South Carolina
- 109 alumni hold masters of science and Ph.D. degrees

The Power of Partnering

The Deep Orange 3 program provides industry partners – entrepreneurs, suppliers and OEMs – with a platform to develop, integrate, showcase and verify new innovations and technologies in a full-vehicle working product. Participating companies, collaborating with students, can explore concepts and technologies they would not have the time or ability to pursue as part of their individual research and development efforts. The knowledge gained directly feeds back to benefit industry and academic institutions.

What's more, industry-relevant teaching teamed with mentoring provides a close alignment of academic and industry practices, preparing future engineers to address challenges the automotive industry will face in the years ahead. Partners such as Altair have given their time and resources to help achieve the objectives of this project.

For example, the application of Altair's technologies taught students how to optimize the vehicle topology and select materials for the right locations with the right thickness, resulting in a vehicle with minimum weight that still fulfilled functional requirements.

In addition to supplying simulation software, Altair staff helped to train the students on how to use the tools. If students needed assistance on concepts or execution, they had access to Altair staff and expertise. The application of simulation tools in the context of the project enabled students to come out of the program with a better understanding of how these tools are applied in a real-world environment.

Measuring Success

The Deep Orange 3 program is characterized by an extensive grading scheme. Students are evaluated individually, by their peers and on the basis of project targets achieved. When students complete the program, they are ready to transition into industry. Students have found their Deep Orange 3 program experience to be relevant and differentiating. As they prepare to enter the commercial workforce, many are armed with a personal "engineering" portfolio to share and discuss with potential employers.

Several graduates of the Deep Orange 3 Program are, indeed, working in the automotive industry. One is now a CAE analyst at the Toyota Technical Center in Ann Arbor, MI. Another is a durability testing engineer at Honda R&D Americas in Raymond, OH. Still another performs vehicle front-end design/layout for AUDI AG in Ingolstadt, Germany.

The Deep Orange 3 program is unlike any other university program: it immerses graduate engineering students into the working environment of the automotive OEMs and suppliers. Each project focuses on applying innovative design processes and tools, such as Altair simulation software, to vehicle development and integrating the resulting design with breakthrough product components, thus providing the students with hands-on experience in vehicle design, engineering and prototyping.

In addition, the Deep Orange 3 program focuses on the vehicle and its infrastructure from an integrated systems perspective. This enables students to tackle complex development problems through collaboration with colleagues who have radically different experiences and responsibilities in automotive design. They push the boundaries of conventional thinking to produce a vehicle that is both groundbreaking and functional. C2R

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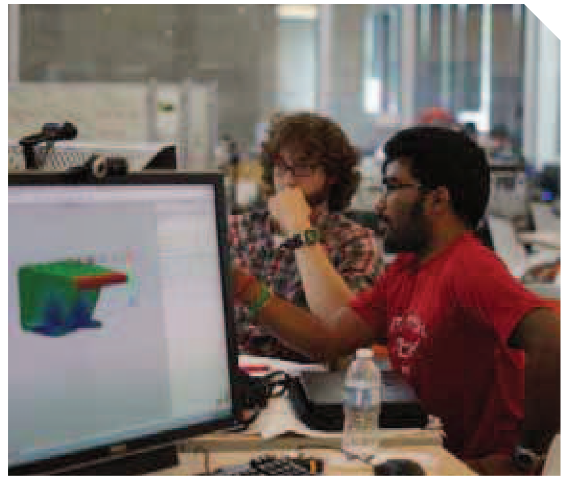
For more information on the Deep Orange 3 program of Clemson University and HyperWorks, visit www.C2Rmagazine.com/2013.



CU-ICAR: Pursuing Automotive Excellence

The Clemson University International Center for Automotive Research (CU-ICAR) is an advanced technology research campus where university, industry and government organizations engage in synergistic collaboration. The 250-acre campus in Greenville, SC, offers the nation's only Ph.D. in automotive engineering.

In addition, industrial-scale laboratories and testing facilities are accessible to companies and professionals for applied R&D in new technology. CU-ICAR's research focus is in seven critical areas: advanced powertrains, vehicle electronics, manufacturing/materials, vehicle performance, vehicle-to-vehicle infrastructure, human factors and systems integration.

CU-ICAR faculty, through investments by private industry and matching funds from the state of South Carolina, include some of the most heavily endowed chairs in the nation including the BMW Endowed Chair in Systems Integration; the BMW Endowed Chair in Manufacturing; the Michelin Endowed Chair in Vehicular Electronics Systems Integration; and the Timken Endowed Chair in Automotive Design and Development.