When the Department of Defense realized that soldiers riding inside its new Mine-Resistant Ambush-Protected vehicles were still being injured by improvised explosive devices, it turned to MAE’s Center for Applied Biomechanics for answers. Since its founding in 1989, CAB has emerged as one of the world’s pre-eminent centers for research on impact biomechanics, computational mechanics, vehicle crashworthiness and crash dummy development. Among other questions, the Pentagon wanted to know why the injuries were occurring, what could be done to prevent them and why they went unnoticed during initial testing.

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As you will read in this newsletter, the department continues to break new ground, thanks to its strengths in research and teaching. Rob Salzar and his team at the Center for Applied Biomechanics, for instance, are conducting the fundamental research necessary to protect soldiers in armored vehicles from the shattering force of improvised explosive device blasts. Members of the department are also doing pioneering work at the frontiers of flight. Funded with a $2.2 million grant from the Air Force Office of Scientific Research, Harsha Chelliah is overcoming obstacles to using a hypersonic engine’s own fuel as a coolant. And Haibo Dong, our newest associate professor, having joined the department this year, has combined video and computation to reveal the complexity — and the beauty — of flexible-winged flight.

We also made advances in education. Partnering with the Department of Systems and Information Engineering and the Department of Electrical and Computer Engineering, we unveiled the Technology Leaders Program for undergraduates interested in electromechanical systems. Originally funded by the NSF and industry, this initiative addresses the need for engineers who combine disciplinary depth with a systems-level perspective.

In addition, the department is distinguished by efforts to support 21st-century manufacturing. Our world-class Mechatronics Laboratory and our Rapid-Prototyping Laboratory (now the Rolls Royce-Advanced Manufacturing Laboratory) are the inspiration for a first-in-the-nation partnership with the Curry School of Education and two local school districts to bring advanced manufacturing and design into K-12 science classrooms. U.Va. engineering and education students will collaborate with lab school science teachers to provide opportunities for students to learn science in a meaningful context. The Office of the Governor is funding the initiative, which is consistent with the national strategy of bringing advanced manufacturing back to the United States.

Our hopes for the future of the department rest on our faculty. That’s why I am pleased to announce that Patrick Hopkins, who received both his undergraduate and graduate degrees here, just received a Young Investigator Award from the Air Force Office of Scientific Research. I would also like to recognize our alumni. Many of you, like Steve Miner, have been dedicated supporters of the department. In the process, you’ve helped us enrich the lives of generations of students.

With best regards,

Hossein Haj-Hariri
Professor and Chair
The lure of hypersonic flight is undeniable, offering dramatically higher speed and efficiency, but the challenges are equally daunting. To achieve speeds of Mach 12 and above, hypersonic aircraft will require a combined-cycle engine that changes its propulsion mode from gas turbine to ramjet to scramjet as it boosts vehicle speed. One goal of the National Center for Hypersonic Combined Cycle Propulsion, led by Professor James McDaniel, is to examine the critical mode transitions required to design the complex engines.

The competition for this $10 million, five-year program was fierce. More than 26 university and industry teams submitted preliminary proposals, and the U.Va.-led team was one of only three groups funded by NASA and the Air Force Office of Scientific Research. “This is clearly the next frontier in flight,” says McDaniel, “We wanted the opportunity to be at its leading edge.”

For NASA and the Air Force, the rationale for hypersonic flight is straightforward: it provides a much more efficient platform to boost payloads such as communication satellites into Earth’s orbit and robotic and human missions into space. That’s because air-breathing propulsion systems do not have to carry oxygen on board for burning the fuel, like rockets do, and can therefore carry more payload.

The center’s research will also contribute to much faster intercontinental commercial flights. While next-generation long-haul aircraft may not be truly hypersonic, their flight times will be a fraction of those of today’s jets, thanks in part to the center’s research.

The center includes 11 academic and industrial partners, including Stanford, Cornell, Boeing and ATK GASL. It collaborates with the Air Force Research Laboratory and several NASA centers, as well as with organizations in Australia and other countries. With this exceptional team of investigators and collaborators, the objective of the center, to meet the challenges of understanding the critical mode transitions and hypersonic propulsion, is indeed becoming a reality.

One hundred and ten years ago, the Wright Brothers pioneered fixed wing flight. Research conducted by Associate Professor Haibo Dong and his colleagues is setting the stage for a new generation of flying vehicles that, like insects or birds, are propelled by flexible wings. “I’m studying flight in nature, both to better understand it and to find ways to improve upon it,” says Dong.

Dong is using an integrated experimental and computational approach to master the fluid dynamics of flexible-winged flight. His starting point is measuring actual insect flight — a real challenge because of their small wing size, the frequency with which they flap their wings and their uncertain movement through the air. Dong developed a new system that combines three high-speed video cameras taking images at 1,000 frames a second and software that stitches the images together to create a three-dimensional image.

There is, however, a low-tech side of his research. “To take advantage of this system, I had to learn how get the dragonflies to fly in between the cameras,” Dong says.

Dong then applied this experimental data to create three-dimensional computation flow simulations and analysis tools to help him understand the wake structure and vortex formation produced by their wing and body movements. His work has been supported by a National Science Foundation CAREER Award and grants from the Air Force Office of Scientific Research.

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A team of CAB researchers led by principal scientist Rob Salzar has begun answering these questions. “These are not the kinds of intrusion injuries you see in a typical accident,” he says. “Because of the thickness of the armor, the floor might move just half an inch, but it’s been driven by 500 to 1,000 Gs of force. This causes complex injuries at the point of contact, the foot and ankle as well as the pelvis.” CAB designed an underbody blast simulator to develop injury criteria for these explosions and is conducting biofidelity tests to support fast-track development of a new crash test dummy for blasts. Next, CAB will focus on mitigating the blast effects to minimize injuries. “Our strengths are our understanding of the battery condition to humans in a variety of different environments and our ability to develop rigs that replicate them,” Salzar says.

The centerpiece of CAB’s 30,000-square-foot facility is its full-scale rollover sled system, capable of rolling a sport utility vehicle at 400 degrees per second and dropping it on a moving roadbed. Senior engineer Jason Kerrigan is using this system to help develop a better rollover test for the National Highway Traffic Safety Administration’s (NHTSA) 5-Star Safety Ratings. The current test measures the strength of the roof and compares it to the weight of the car. NHTSA has asked CAB to use its sled to help it better characterize the injuries that occur, design a repeatable test and develop an appropriate dummy. “This work has attracted the attention of major car manufacturers, who have seen CAB as a resource to help them make their cars safer,” Kerrigan says. “That’s something we’re always happy to do.”
One of the department’s new faculty hires under the Rolls-Royce partnership, Assistant Professor Patrick Hopkins, began his career as an undergraduate and graduate student at U.Va. “The Engineering School played such a formative role in my development,” he says. “It feels great to come back and make a contribution.”

As a student at U.Va working with Professor Pam Norris, who is now associate dean for research and graduate programs, Hopkins gained a thorough grounding in nanoscale heat transfer, now the unifying theme of his research. At the nanoscale, Fourier’s Law breaks down, power densities spike and heat transfer physics begins to resemble that of the sun. This is particularly an issue for computer chips. Hopkins has been conducting research on how nanoscale imperfections, such as surface roughness and compositional disorder, can change thermal boundary conductance, which in turn opens the possibility that these qualities can be tuned to control thermal transport.

Collaborating with Professor Mool Gupta of the electrical and computer engineering department, Hopkins recently discovered a material with the lowest thermal conductivity of any fully dense solid. “You learn a lot from understanding these extreme materials,” he says. “By studying the best and worst thermal insulators, we can develop new physics and engineer novel devices.” A century ago, Albert Einstein originally hypothesized that oscillations are necessary for heat transfer. For most materials this turns out not to be the case, but for this extreme insulator, Einstein was right.

Hopkins also draws on his U.Va. experience for his teaching. “I took courses in many overlapping different fields as an undergraduate,” he says. “I’d cover the same material from a different perspective in physics or applied math courses that I would in my mechanical engineering courses. The value of that repetition and review shapes my approach as a teacher.”

Hopkins recently received a Young Investigator Award from the Air Force Office of Scientific Research. He will use the funding to study electron dynamics during high-power, short-pulsed laser interactions with solids and interfaces.

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As a researcher, Professor James McDaniel (Aerospace ’71) has an exceptional record. As principal investigator for the National Center for Hypersonic Combined Cycle Propulsion, McDaniel leads a consortium of universities, companies and government agencies whose goal is to develop the advanced modeling capability needed to design propulsion systems for hypersonic vehicles. He has also authored or co-authored more than 150 refereed journal articles and conference papers and presentations.

But the U.Va. graduate is equally devoted to his teaching. He has taught the fourth-year Capstone aerospace design class for more than two decades, focusing each class around a competition sponsored by NASA or the Federal Aviation Administration. McDaniel divides the class into the kinds of functional teams that would be used to conduct similar projects in industry. He keeps close tabs on their work, meeting with teams regularly, providing the fundamental knowledge they need to move their design forward and pulling them back if they go astray. At the same time, he says, “I like for it to be their project.”

His classes have taken on a number of different projects. In 2011, for instance, his students were asked to design an environmentally friendly aircraft that would produce dramatically reduced emissions; in 2009, it was a small supersonic commercial airliner producing just a low sonic boom. On both occasions, they won the competitions. In fact, McDaniel’s teams have won six times in the last 12 competitions. McDaniel is extremely proud of his students’ accomplishments. “We send students from the design class to the best universities and companies in the world,” he says.

Steven Miner’s experience as an undergraduate and graduate student in the department influenced his career’s trajectory. After a decade working for industry, he moved to academia. Miner has been a professor of mechanical engineering at the U.S. Naval Academy for almost 25 years.

After earning his bachelor’s and master’s degrees from the University, Miner (MAE ’79, ’80, ’87) took a position with Westinghouse, and returned to Westinghouse after he completed his doctorate. “After I came back, I began thinking about my instructors at U.Va., people like Ron Flack, John Thacker, Lloyd Barrett and Tim Scott, and they really seemed to enjoy the academic environment and interacting with students,” he says. “That led me to switch.”

It turned out to be a wise decision. “The time I spend in the classroom is the most enjoyable part of my day,” Miner says. In his interactions with students, Miner builds on the lessons he learned from his own student experience. “At U.Va., faculty were always there to help you, but you were expected to take responsibility for the work you needed to do to be successful,” he says. “This is something I try to convey to my students.”

Miner has been a sustained contributor to the department. “I really appreciate the education I received there, especially my undergraduate years,” he says, “and I give back by trying to support Capstone and other projects that are hands on. There’s a lot of value in them.”
GRADUATE STUDENT —
RYAN JOHNSON

Ryan Johnson is not alone in being drawn to flames, but his attraction is intellectual, not instinctual. He is interested in uncovering the complex process of combustion that occurs when a mix of fuel and air flow over a reactive plate. But Johnson doesn’t study ordinary combustion. His challenge is to model an inherently complex process — the oxidation of hydrocarbon fuels typically consists of hundreds of species generated during thousands of reaction steps — at speeds in which the hypersonic flow of fuel and air overlaps the speed of combustion itself. Johnson’s chosen technique is modeling, which enables him to quantify these processes at a level of detail not easily observed experimentally.

As an undergraduate at the University, Johnson was a student leader of Hy-V, the department’s hypersonic scramjet program. Professor Houston Wood suggested he contact Professor Harsha Chelliah about graduate study. “Professor Wood told me that [Chelliah’s] group was focusing on a fundamental problem and that students would write their own code.” This appealed to Johnson. “I’ve always loved mathematics,” he says. “I particularly enjoy putting my ideas to work in a computational environment.” For his dissertation, Johnson will study laser-induced ablation over a carbon plate.

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