COLLEGE OF ENGINEERING

Momentum!

Winter 2015

ROBOTS, RACE CARS, AND ROCKETS

Oregon State UNIVERSITY

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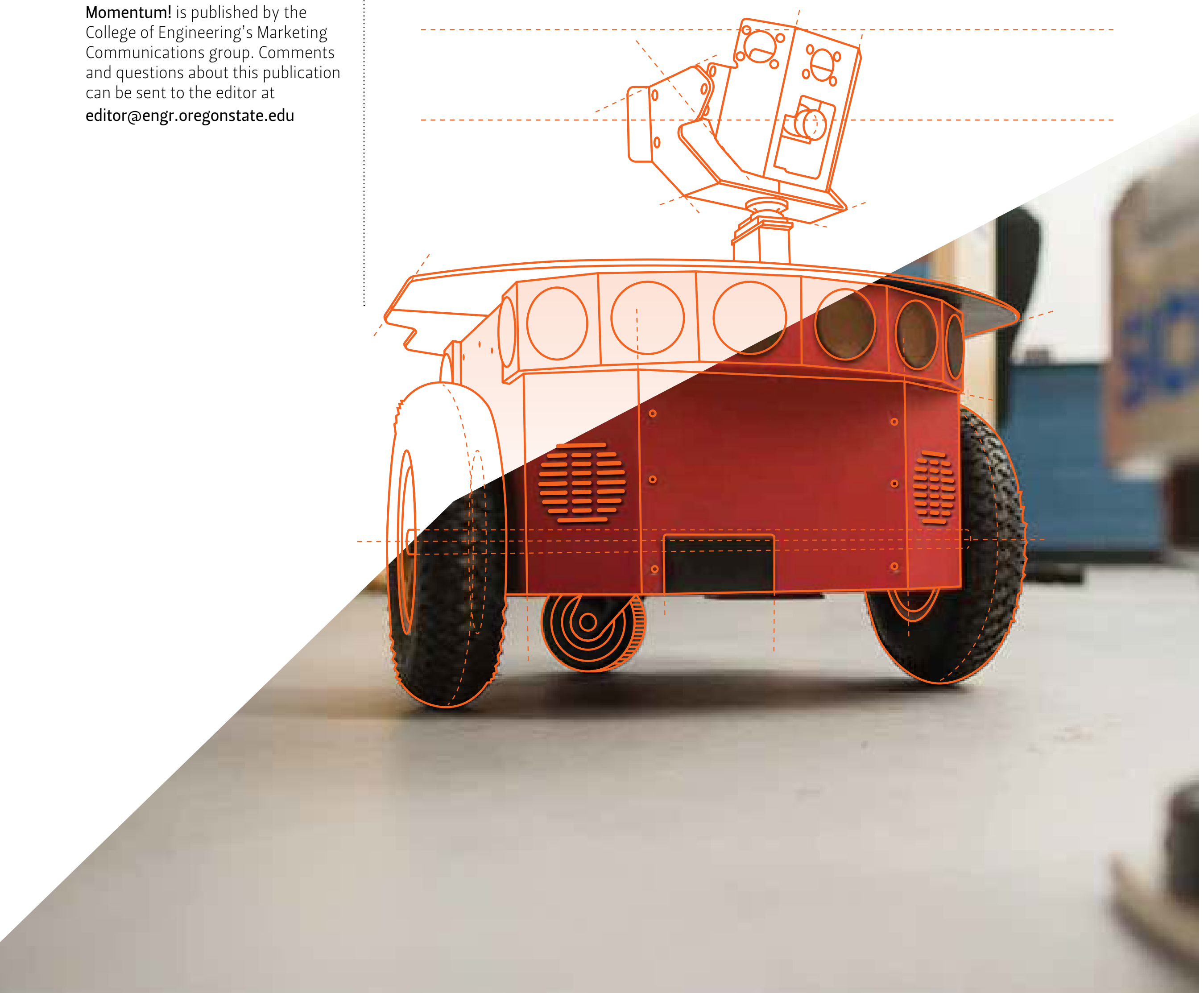


Dean's message

Only a few decades ago, the idea that robots would be stocking warehouses, assisting physicians in the operating room, and conducting covert operations overseas was the stuff of science fiction. But these are common occurrences today. So is it too much to imagine the day when a sidewinding robot will rescue a car accident victim trapped 100 feet down a steep, barren mountainside? Or the day when a bipedal robot will be seen running across a battlefield to locate and bring back wounded soldiers?

Researchers in the College of Engineering can imagine these scenarios, and they're making technology breakthroughs that will make your head spin. We're in the process of creating one of the nation's strongest robotics programs right here at Oregon State, and already we have seen some amazing projects come to fruition. In this issue, you can read about how it all started and get an introduction to some of the researchers and their projects. As researchers in artificial intelligence and machine learning join forces with mechanical engineers, who knows where the technology will lead us.

It's not just our faculty who are creating a whole new future in front of our eyes. The combined energy, enthusiasm, tenacity, dedication, and raw talent of our engineering students nearly takes my breath away at times.

Our student-led Global Formula Racing team consistently wins international championships by building the most robust race cars among a huge field of talented competitors. More importantly, the students involved are learning to work within a globally distributed design environment — a skill that makes them highly desirable to employers.

When a group of 27 undergraduates with no experience in building rockets came together just because they wanted to have fun and test themselves, they ended up building a rocket that garnered awards the first time it was launched. Take some time to read the story, which, as the writer points out, could be the basis for a movie script.

Is it any wonder that our Oregon State engineers are sought by employers like Boeing, SpaceX, Nissan, CH2M HILL, and NASA? We give our students a solid grounding in fundamentals while offering them plenty of opportunities to translate their newly acquired knowledge into real-world projects that provide depth of understanding in a particular discipline. Hands-on experience in an academic culture that values collaboration provides the perfect training ground for adding the leadership skills that employers seek. It's a formula that transforms robotics, launches rockets, and keeps our graduates leading the pack — not just on the racetrack, but in their budding careers.

Go Beavs!

Scott A. Ashford, Ph.D.
Kearney Professor and Dean
Oregon State University
College of Engineering

STUDENT TEAM WINS WITH CROSS-CULTURAL COLLABORATION

By Marie Oliver

Oregon State University is proud to nurture a strong culture of collaboration among its students and faculty, and nowhere does that value become more evident than at Formula SAE (Society of Automotive Engineers) events.

Formula SAE is an automotive design competition that attracts teams from about 500 universities worldwide. Each year, teams build a race car from the ground up and race it in competitive events around the world.

Oregon State's team, Global Formula Racing, is a cooperative venture with Duale Hochschule Baden-Württemberg – Ravensburg (DHBW–R), Germany, and it consistently leads the pack.

"We're the most successful team in the world," said Bob Paasch, Boeing professor of mechanical engineering design and U.S. advisor for Global Formula Racing. "We have won more competitions in the last five years than any other team in the world."

This is an amazing accomplishment, considering that Oregon State doesn't offer a degree in automotive engineering. Many of the universities Global Formula Racing competes against do have strong automotive engineering programs and are located in areas where automobile manufacturing is one of the major industries.

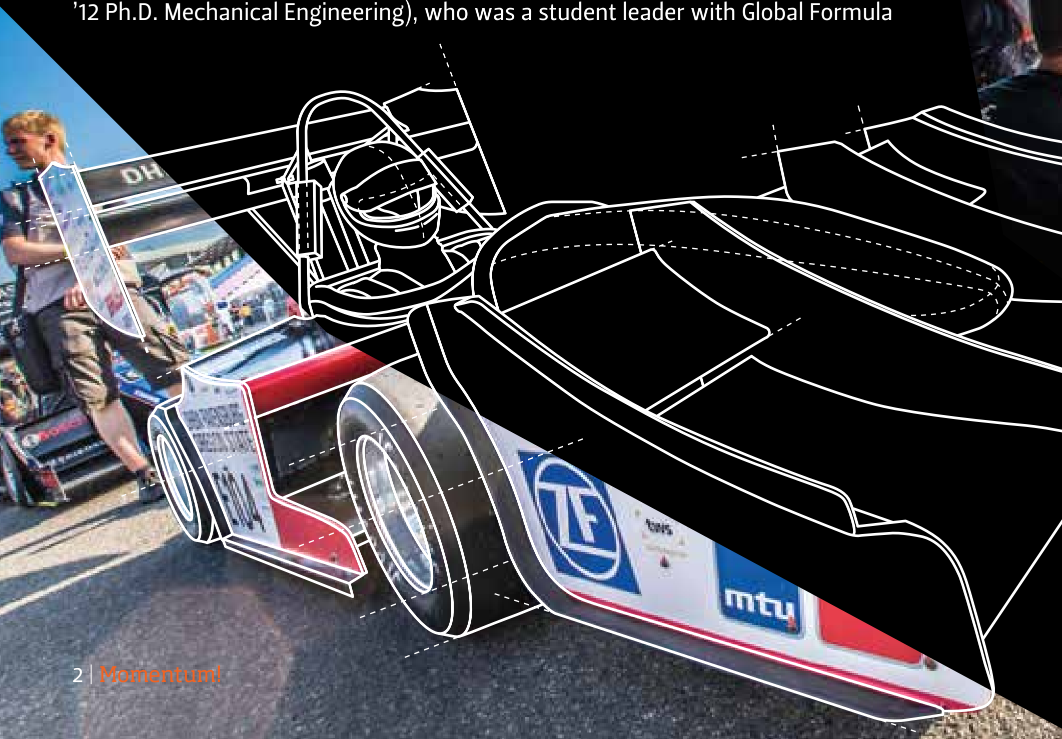
"Oregon State isn't focused on motor sports; we're not focused on automotive; we're just focused on good engineering," said Chris Patton ('06 B.S., '09 M.S., '12 Ph.D. Mechanical Engineering), who was a student leader with Global Formula Racing when it first got started. "We try to engineer the car as best we can, and then we go out and compete against teams that are focused on automotive engineering and racing. And we're beating them."

Students at Oregon State have been involved in Formula SAE competitions since 1987, long before Global Formula Racing got started, but the teams had limited success in the early days.

"For the first few years I was on the team, it was really kind of a struggle," said Bill Murray ('09 B.S., '12 M.S. Mechanical Engineering) who joined the team as a freshman in 2004. "We were a small group with lots of ambition, but despite our best efforts, we didn't seem to be able to complete a competition."

In 2005, Oregon State alumnus Thomas Nichol ('96 Ph.D.), who had become a professor at the DHBW Ravensburg, called Paasch looking for United States internship opportunities for two students. Paasch placed the students on the Formula SAE team. The collaboration between the universities really began when the students went back to Ravensburg and convinced their university to start a Formula Student team.

For the next few years, Oregon State students traveled to Ravensburg as instructors or project advisors and German students came to Corvallis as interns. Since the German students were competing in Europe and the Oregon State team was competing in the United States, they freely shared ideas about how to build a successful car. "The collaboration just kept getting closer and closer," said Paasch.



By 2008, Paasch was noticing that industry was looking for engineers who were adept at working in a globally distributed design environment. "Companies like Boeing distribute design and manufacturing throughout the world," he said, "and we weren't giving students exposure to this while they were in university. So that was the motivation: to give students experience in globally distributed design and manufacturing, with the idea of making our graduates more competitive."

In summer 2008, a student leadership team traveled to Germany and began developing the foundation for the fledgling partnership. "We went to competitions and really began laying the seeds for the collaboration between us by building those personal relationships," said Murray.

The two universities signed a memo of understanding and developed a five-year plan for working together.

"The first year was really proof of concept," said Murray. Initially, the Germans and Americans built separate cars. "At the end of it, we evaluated which car did better, which concepts did better in competition, and used that information to decide what kind of car GFR was going to build going forward."

Today's relationship is sealed with a comprehensive collaboration contract between the two universities, and the wins are stacking up.

Paasch credits Hillary Shoop ('10 B.S. Industrial Engineering) with laying a strong foundation of collaborative teamwork that helped make the team so successful.

"These were very different schools with two different cultures, coming together to start working on this project," said Shoop. "Besides obvious issues like time zones and language barriers, there were culturally-based challenges like work-ethic styles, communication methods, and problem-solving approaches we had to understand. The leadership team was responsible for making sure these issues weren't being swept under the rug."

One value of the cross-cultural partnership became evident when the team began preparing and testing their verbal presentations to panels of industry judges at the competitions in different countries. Shoop was responsible for giving business/marketing presentations, and she said the team learned through trial and error how important it was to keep cultural differences in mind when tailoring the presentation to different international audiences.

"A presentation that worked in the U.S. did not necessarily work in Europe," she said, and input from the German students made the difference.

The team learned to collaborate as much through their failures as their successes, said Shoop. "We had to get out of thinking 'that's not important' or 'that's not how we do it' and start thinking about how adopting and respecting the other culture would lead to a much more successful presentation. That was something our whole team needed to learn in order to be successful."

After graduating, Patton got a job with Caterham Formula One, an international racing team based in the United Kingdom, and is now working with Nissan on its LMP1 series. Murray had two excellent job offers upon graduation and is now working for Joe Gibbs Racing.

But Patton and Murray are the exception to the rule, because most team members don't go into automotive engineering after they graduate. Shoop interned at the international engineering firm CH2M HILL and moved right into a full-time job there after earning her bachelor's degree. She is one of the lead CH2M HILL engineers on the design of a new semiconductor manufacturing plant in Grenoble, France. Additionally, SpaceX has hired several other students who were involved in the team.

The consensus among the three former students is that their involvement with Global Formula Racing helped them build global awareness and a valuable set of professional skills on top of the skills and knowledge they needed to be successful in their engineering disciplines. They were prepared to step into positions that required experience in and an understanding of what it takes to work in a globally distributed engineering environment. **M!**

GLOBAL FORMULA RACING'S FIRST PLACE FINISHES:

2014	Formula Student Austria	Formula Student SAE Michigan*	Formula Student Germany	Formula Student Spain
2013	Formula Student Germany			
2012	Formula Student Austria	Formula Student SAE Michigan*		
2011	Formula Student Austria	Formula Student SAE Michigan*	Formula Student Germany	
2010	Formula Student Austria	Formula Student Italy	Formula Student SAE Michigan*	
2009	Formula Student Austria			

*De facto U.S. National Championship

CREATING

ROCKET SCIENTISTS FROM SCRATCH

By Gregg Kleiner

It's a story that seems made for Hollywood:

An engineering student stumbles across a notice about an international rocket competition and casually asks a couple of his roommates if they want to build a rocket. The roomies collectively respond, "Cool! We're in!"

Several other engineering students get wind of the project and sign on to the fledgling team. Initial planning meetings draw more than 40 students, all excited to be part of the rocket project.

The only problem is that none of the students has any experience designing and building high-powered rockets, let alone a 10-foot-tall, 50-pound, solid fuel, Level III rocket capable of reaching 10,000 feet while carrying a payload of at least 10 pounds.

But that doesn't deter them.

Nor does it deter the middle-school student who signs on when the team does some K-12 outreach. The eighth grader wants to design a special payload that includes a GoPro camera that will deploy at peak trajectory and film the rocket's descent back to Earth, slowed by two parachutes.

Twenty-seven undergraduates in mechanical and electrical engineering put forth a Herculean effort that includes countless meetings, long hours of research in libraries and labs, late nights with gallons of Red Bull, hands-on testing and retesting, successes and setbacks.

Nine months later, the team packs up and drives cross-country to the Experimental Sounding Rocket Association (ESRA) Intercollegiate Rocket Engineering Competition in the desert near Green River, Utah.

They beat 22 other teams from around the world with an almost perfect launch of 10,280 feet and take home the $1,000 prize in the Basic Category.

They also win the $100 Payload Prize, thanks in part to the middle-schooler's contribution and the team's ingenuity. Many team members land prestigious summer internships in the aerospace industry at places like Boeing, SpaceX, NASA Ames, and elsewhere.

This is no Hollywood movie — it's a true story that happened at Oregon State University, and it just might alter the course of aerodynamics at the College of Engineering.

The team project fostered camaraderie and a sense of collaboration that the team's faculty advisor, Nancy Squires, called "absolutely amazing." Squires came to Oregon State in 2005 following a career in the aerospace industry, interspersed with teaching stints. She said the students made every part of the rocket, except one retaining ring, from scratch.

"They rolled the carbon fiber into tubes, built the motor, mixed the fuel, everything — including how to collaborate as a team and network with industry," Squires said. "My role was really just to provide moral support, give mission success speeches, and bring cookies to the launches. They did everything themselves."

Pretty impressive, given that Oregon State doesn't even have an aerospace engineering program — something many of the competing teams were part of. But Oregon State does have an American Institute of Aeronautics and Astronautics (AIAA) student club, founded two years ago by Roberto Albertani, associate professor of mechanical engineering, and engineering students Brandon Thoennes and Michael Roos.

In addition to Squires and Albertani, the team found mentorship from three members of the Oregon Rocketry Club, which has a launch site near Brothers, Oregon.

Michael VanderPutten, a senior who served as project lead on the team and was interning at Boeing last summer, said the biggest challenge was the lack of knowledge and experience.

"Our team's main hurdle was the fact that none of us had done anything like this before," he said. "Other schools had been participating in the competition for several years. So our biggest challenge was the learning curve and knowing how things had to work for the entire system."

The team addressed this lack of knowledge by traveling to the Brothers launch site, where they camped and networked and ultimately met the mentors — Joe Bevier, Steve Cutonilli, and John Lyngdal — who would work closely with the team.

"They were so helpful…Steve let our team into his mobile lab, where we formulated and mixed our own solid fuel — jet black to go with the Beaver orange flames," VanderPutten said. "Joe taught us how to lay fiberglass for coupler tubes, and we rolled our own carbon body tubes at Innovative Composite Engineering."

VanderPutten said the project definitely prepared him for work in industry and changed his perspective on classroom lessons. "When I applied what I was learning in class to this hands-on project, I was suddenly much more interested in the coursework and worked as hard as possible."

The project also influenced VanderPutten's decision to return for graduate school this fall, where he will study thermal fluid flow.

"I wasn't even considering grad school before this project," he said. "But it's changed lots of things." He'll be involved with the rocket team again this year, in a managerial role. This summer, after his workday ended at Boeing in Seattle, he logged a couple hours each evening planning for next year's project.

Sierra Bray, who will be a senior and serve as the team's vice president this year, credits the project with helping her land a summer internship at NASA Ames Research Center, where she worked on a new flight simulator for helicopters.

"One of the key things we learned is that testing is really important," she said. "A lot can go wrong."

The team did two test launches in Brothers leading up to the competition. On the first one, the main parachute deployed too early, so the rocket, named "Terminal Gravity," drifted a long distance, making recovery challenging. But it didn't explode into a ball of fireworks, which happened to some rockets at the ESRA Competition — one before it even left the launch pad.

Whitney Hopple, a senior on last year's team, said she will never forget the late nights working in the lab. "Even at the most difficult moments, someone would make a joke, we'd all have another Red Bull, and enjoy staying up another few hours until the job was done," she said. "No one ever lost sight of the end goal."

Hopple says the project helped her secure an internship at SpaceX in Los Angeles this fall, where she will work on composites for rockets.

Squires said that student participation in competitions is a big plus to prospective employers, and Oregon State students stand out as industry-ready.

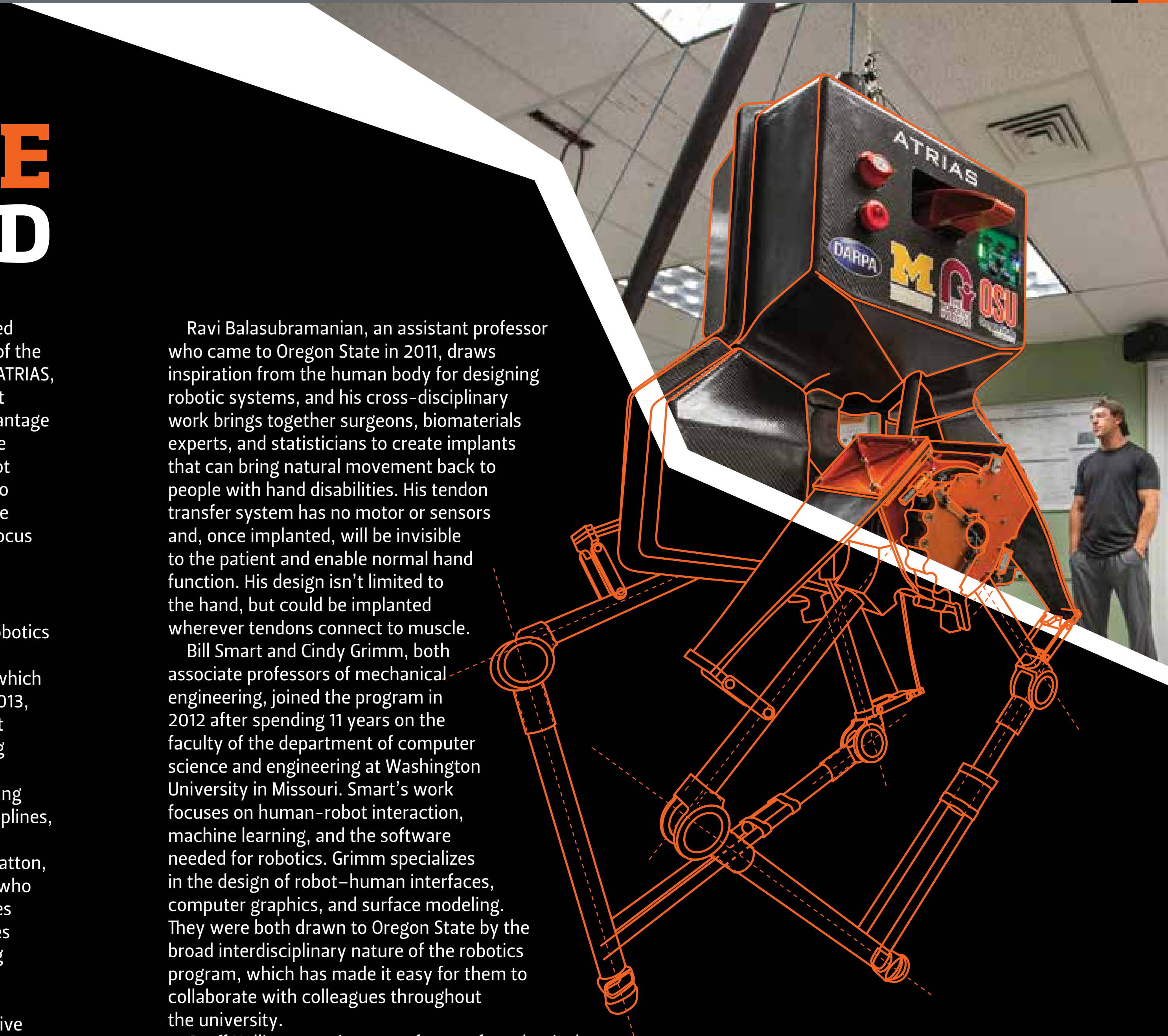
"I've taught at Stanford, UC San Diego, the Colorado School of Mines, and elsewhere, and the students here at Oregon State are the best I've ever worked with," she said. "They have a work ethic and a desire to succeed that companies notice. They're competing with graduates from top aerospace programs, and our students are getting the jobs."

Next year, the team plans to compete in the Advanced Category at the ESRA Competition, which means they need to build a rocket that can reach 25,000 feet.

"It will be a bigger challenge," Bray said. "But since we did so well this year, we want to see how well we can do at the next level."

With so many members from last year's tight-knit and talented team returning next year — including four as graduate students, it just might make for another happy, high-flying Hollywood ending. Stay tuned for the sequel. **M!**

BUILDING A FUTURE IN A FUTURISTIC FIELD



Many technology leaders have likened the current growth of robotics to the growth of the Internet in the 1990s. Robots are now enlisted to heal people, explore outer space, aid emergency workers, support soldiers on the battlefield, teach our children, and keep our houses clean. Sales of manufacturing, medical, and service robots are increasing at annual rates of more than 30 percent, creating both supply and new demand for more robots.

Ignition

The seeds of the Oregon State University robotics program within the School of Mechanical, Industrial, and Manufacturing Engineering were planted when the former head of the school, Belinda Batten, encouraged a group of students to participate in the 2005 DARPA grand challenge. Participants in the competition created a driverless car. Using a chassis from an earlier student competition, the small team competed with programs that substantially outspent them and qualified for the semifinal stage.

Kagan Tumer came to Oregon State after a nine-year career as senior research scientist and group lead for the Intelligent Systems Division at NASA's Ames Research Center. At that point, although individual researchers at Oregon State were well known for their research in artificial intelligence, computer vision, machine learning, and other disciplines critical to robotics, the robotics program that exists today hadn't yet been officially established.

In 2006, Tumer led the search to hire the first robotics faculty member, which resulted in bringing Jonathan Hurst to campus. Hurst had just completed a doctorate in robotics from Carnegie Mellon University and was drawn to the new program in Corvallis because he saw it as fertile ground for something big. "There was very good leadership in the department, and there was support and freedom to build a research group or a program or anything we wanted to do," he recalled. "I got the sense that the sky was the limit."

Hurst's research focuses on the science of legged locomotion, specifically on the passive dynamics of the mechanical system. His group designed and built ATRIAS, a bipedal robot. ATRIAS has springs in just the right places and legs of just the right shape to take advantage of passive dynamics and enable high-performance running and walking outdoors. Of course, the robot will only function with a good control algorithm, so developing control theory that cooperates with the passive dynamics is another important research focus for Hurst.

Acceleration

Over the five years following Hurst's arrival, the robotics program expanded at a fast and furious pace. The college renovated a space for Hurst's laboratory, which he named the Dynamic Robotics Laboratory. By 2013, the research group had grown to encompass eight faculty members, and it is still hiring. For incoming professors, the draw includes the chance to work with other departments within the university, taking advantage of a priceless opportunity to cross disciplines, and ultimately to help countless others.

"I was really excited to come here," said Ross Hatton, an assistant professor of mechanical engineering who also came to Corvallis following his doctoral studies at Carnegie Mellon. "There were good opportunities for collaborative, interdisciplinary research among the faculty." Hatton is developing fundamental mathematical tools for studying locomotion. His research on snakes and spiders provides the creative foundation for models that manipulate movement from a single point of control and will support efforts to combine natural and robotic systems. "Biology has many examples of systems that move over rough and complex terrain, and we're seeking to bring those ideas into robotics," he said. (See the article on page 11, *Sidewinder rattlesnakes help build a functional robot*.)

Ravi Balasubramanian, an assistant professor who came to Oregon State in 2011, draws inspiration from the human body for designing robotic systems, and his cross-disciplinary work brings together surgeons, biomaterials experts, and statisticians to create implants that can bring natural movement back to people with hand disabilities. His tendon transfer system has no motor or sensors and, once implanted, will be invisible to the patient and enable normal hand function. His design isn't limited to the hand, but could be implanted wherever tendons connect to muscle.

Bill Smart and Cindy Grimm, both associate professors of mechanical engineering, joined the program in 2012 after spending 11 years on the faculty of the department of computer science and engineering at Washington University in Missouri. Smart's work focuses on human-robot interaction, machine learning, and the software needed for robotics. Grimm specializes in the design of robot–human interfaces, computer graphics, and surface modeling. They were both drawn to Oregon State by the broad interdisciplinary nature of the robotics program, which has made it easy for them to collaborate with colleagues throughout the university.

Geoff Hollinger, assistant professor of mechanical engineering, is striving to develop planning, decision-making, and learning techniques to improve robotic systems in the air, on land, and in the ocean. One of his major research thrusts is the development of autonomous capabilities for underwater vehicles, which requires working at the intersection of robotics and oceanography. "The autonomous robotic systems I design have the potential to revolutionize the way we gather scientific data, to improve the efficiency of our agricultural production, and even to save lives by assisting search and rescue teams," Hollinger said.

Cruise control

New master's and Ph.D. programs in robotics begin this fall, and the robotics group is working together to recruit students, acquire a shared research space, and build an international reputation. Despite the program's nascent stage, its reputation is growing. "The international robotics community knows the people we've hired," Hurst said. "In addition, students are very excited about the robotics program, and companies are interested in hiring them."

In late 2013, Oregon State assumed stewardship of the Robot Operating System (ROS) software infrastructure. ROS is an open-source software infrastructure for robotics that is rapidly becoming the de facto standard in academia and industry and is mandated in a number of well-funded government programs. The OSU Open Source Lab is now the primary hosting site for ROS, supporting an estimated 100,000 users worldwide. This is just one more step to cementing Oregon State's position as a hub for robotics.

The continual contributions coming out of the program reflect the nature of the burgeoning robotics field. "This growth is a result of a few things," said Hurst. "First, robotics is a growing field, with new funding opportunities, new industries, and top faculty candidates making new discoveries in this relatively uncharted territory. Second, OSU is growing, and the College of Engineering is responsible for a large percentage of that growth, which necessitates more hires. Third, the robotics faculty has been successful in creating strong, well-funded research programs. Finally, the department heads and the dean have supported the growth of the robotics group in an effort to help build on our success, stay ahead of technology trends, and make the school as a whole stronger."

Together with the world-class Intelligent Information Systems group in the School of Electrical Engineering and Computer Science, Oregon State is on its way to becoming one of the nation's strongest academic players in the field of robotics. **M!**

SIDEWINDER RATTLESNAKES

HELP BUILD A FUNCTIONAL ROBOT

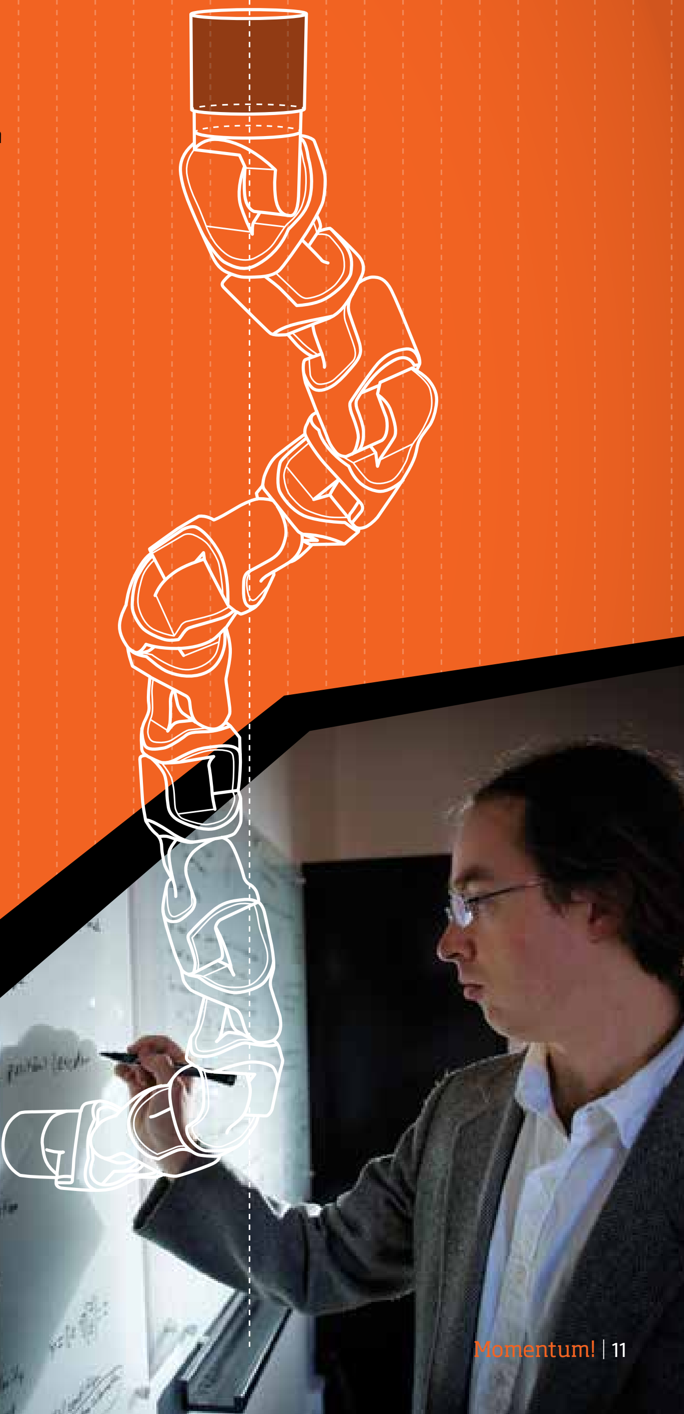
By David Stauth

Snakes can crawl, swim, climb poles, hang from trees, and burrow into holes. Some species can even glide through the air. And for certain robotic missions of the future, such as search and rescue, they seem to be ideal models for building a robot.

Researchers from Oregon State University, the Georgia Institute of Technology, Carnegie Mellon University, and Zoo Atlanta recently completed a collaborative research project in which they developed a snake-like robot that can ascend sandy slopes with functional and highly efficient motion that mimics a sidewinder rattlesnake. They achieved their goal by combining physics and biology within a robotics and mathematics framework, observing what real snakes can do and using those observations to make a functional robot. They used that robot to test hypotheses about how the animal achieves its motion.

"The snake is one of the most versatile of all land animals, and we want to capture what they can do," said Ross Hatton, an assistant professor of mechanical engineering at Oregon State who has spent years studying the mathematical complexities of snake motion and how it might be applied to robots.

Until the 1930s, almost nothing was known about the peculiar style of the sidewinder, which can glide up sandy slopes with an ease that would stymie a legged robot — or for that matter, embarrass most humans who ever tried to climb a sand dune. The snake lifts part of its body from the ground as a way to move more quickly over granular or slippery terrain, adjusting how much of its belly makes contact with the ground and applying whatever pressure is necessary to counteract slippage based on the gradient.

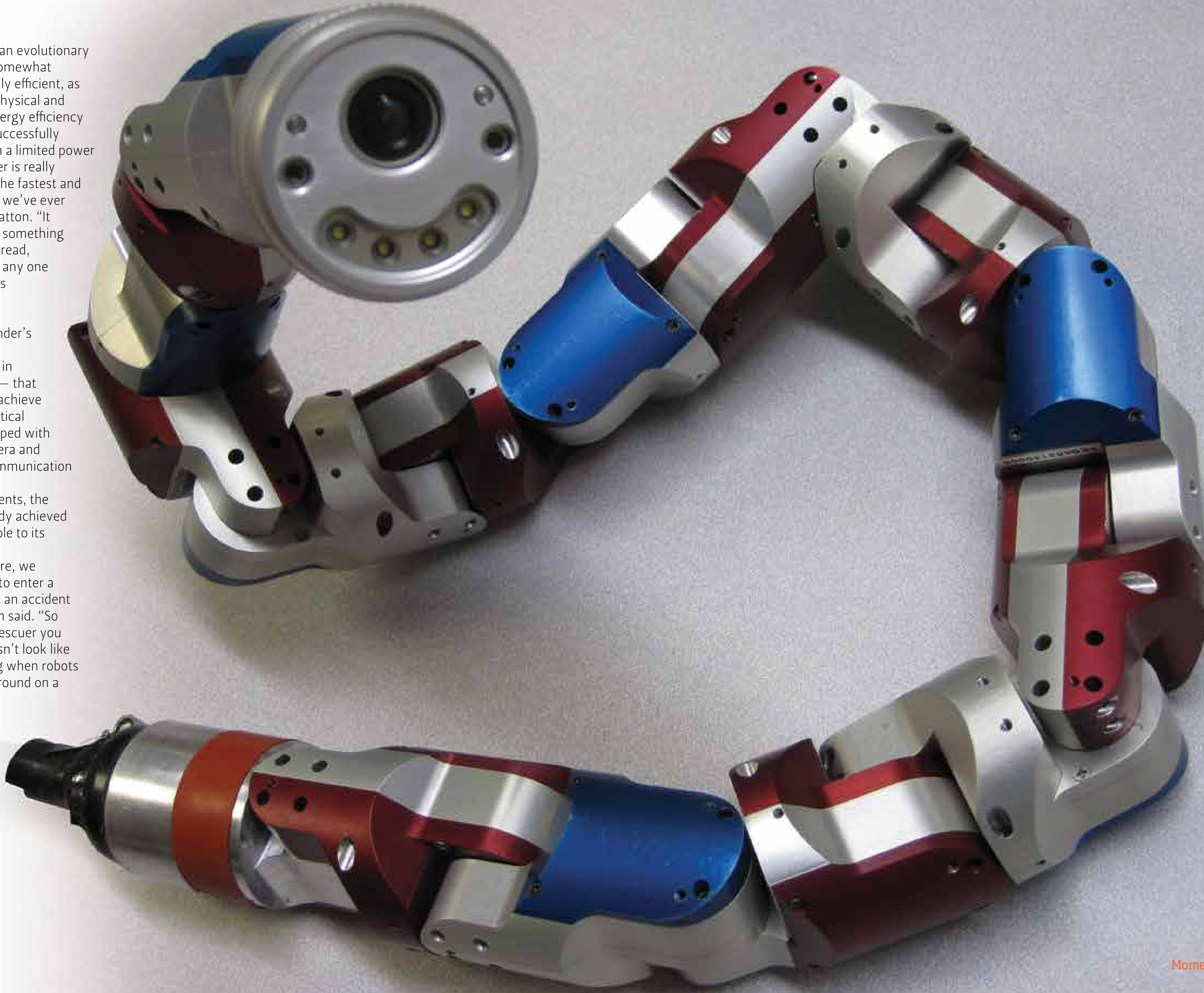


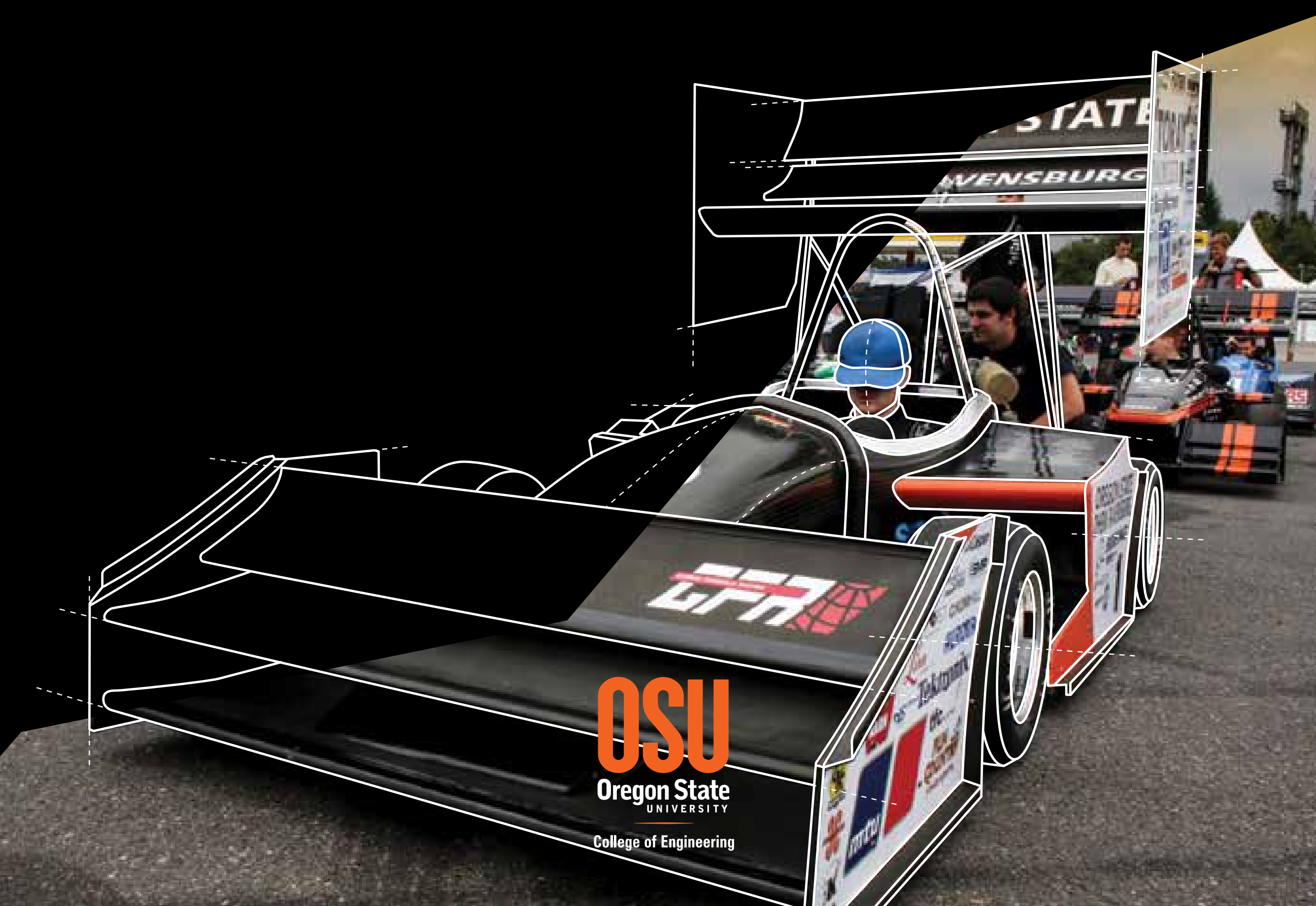
The snake's sidewinding is an evolutionary adaptation that can appear somewhat awkward, but is actually highly efficient, as Hatton determined through physical and mathematic analysis. That energy efficiency can be critical for robots to successfully move over varied terrain with a limited power supply. "The desert sidewinder is really extraordinary, with perhaps the fastest and most efficient natural motion we've ever observed for a snake," said Hatton. "It effectively turns its body into something like a rolling wheel or a tank tread, minimizing the energy lost at any one point while the center of mass moves smoothly forward."

Robotic snakes that can duplicate some of the sidewinder's feats will have many motors working in combination — 16 in the robot used for this study — that need careful coordination to achieve the required motion. For practical usage, they will also be equipped with other devices, such as a camera and microphone for real-time communication and audiovisual recording.

After numerous improvements, the robotic sidewinder in this study achieved mobility over sand, comparable to its natural counterpart.

"Some day in the near future, we may be using robotic snakes to enter a dangerous pile of rubble after an accident to help find survivors," Hatton said. "So don't be too surprised if the rescuer you see crawling toward you doesn't look like a human. The days are ending when robots are just something that roll around on a flat, hard surface." **M!**





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