The VT-BAJA vehicle entry earned 16/105 at BAJA SAE in Cookeville, Tenn., in April of 2013. This vehicle is the lightest produced by Virginia Tech for this event. On the left is the University of Pretoria, South Africa, BAJA vehicle that took 19/105 at the same event. Virginia Tech served as host for the South African team.

The Virginia Tech Motorsports car performs during the endurance competition at the Michigan International Speedway. The Virginia Tech team earned 13/125 at the Michigan Formula SAE competition in May of 2013. The vehicle utilizes a full aero-package consisting of front and back wings under the tray.
A “hands-on, minds-on” approach has led to a tradition of success for Virginia Tech engineering students — in the classroom, as members of award winning competition teams, and later as practicing engineers in the workplace.

Established in 1998, the Joseph F. Ware, Jr., Advanced Engineering Laboratory is the focal point for undergraduate design projects in the College of Engineering. Ware, a 1937 mechanical engineering graduate, and his wife, Jenna, saw a need for a facility dedicated solely to undergraduate student projects and generously funded the conversion of the former Virginia Tech military laundry building. Mr. Ware passed away in 2012 and Mrs. Ware continues to support projects in the design laboratory. The lab is an integrated 10,000 square foot project center complete with numerous work bays, a welding shop, a machine shop, and a computer design lab. A multi-use project bay has recently been added. This facility provides a unique learning environment for engineering students from various majors with currently over 420 students involved in 19 projects. Some students receive academic credit, while others serve as volunteers. Few engineering schools in the world approach Virginia Tech’s level of participation in student design-and-build projects and competitions. Students may become involved as early as their freshman year.

Corporations, universities and colleges, and K-12 groups visit the lab annually to see Virginia Tech engineering students at work. Each year over 1,200 people tour the Ware Lab, offering comments ranging from, “I wish we had this when I was in college,” to “this is the future of effective engineering undergraduate education.” Corporations and businesses are impressed with the students in the Ware Lab who are allowed to sharpen theoretical and computational skills learned in the classroom by working on challenging, viable engineering design projects.

Through public service team participation in world-class competitions, the Ware Lab continues to be the “front door” to Virginia Tech’s College of Engineering.
Mr. Dewey Spangler, Jr., PE, is the manager of the Ware Lab and instructor for the engineering education department. He works with student teams, develops corporate sponsorships, and coordinates visits to the lab for prospective students and educational groups to promote engineering as a profession. He holds a BS and MS in civil engineering and a MENG in mechanical engineering, all from Virginia Tech.

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Mr. Doug Harold is the Ware Lab supervisor responsible for the daily operation of the machine and welding areas, performing safety training and providing assistance to students engaged in project fabrication. He holds a BS in biology and earth science from Tennessee Temple University and an MS in engineering mechanics from Virginia Tech.

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For more information about the Ware Lab: www.eng.vt.edu/warelab/
Arthur C. Klages, a 1942 industrial engineering graduate, donated tools and equipment needed to furnish the Ware Lab machine shop. Equipment in the shop includes: three milling machines, three lathes, drill presses, a band saw, a shear, an English wheel, and various grinding and cutting machines.

In addition, the welding shop is equipped for Gas Metal Arc Welding (GMAW), frequently referred to as MIG welding; and Gas Tungsten Arc Welding (GTAW), frequently referred to as TIG welding; and has a plasma cutter and sand blaster.

Students working in both facilities have the opportunity to receive training on a wide variety of machines providing a firm understanding of manufacturing, fabrication, and construction methodologies.

 Ware Lab students who complete safety certifications have access to modern CNC equipment.
The Ware Lab hosts a 24/7 design lab that is available to students to work collaboratively on engineering design projects. This lab is heavily utilized by team members using computer-aided design (CAD), finite element analysis (FEA), and computational fluid dynamics (CFD). Facilities are also available for team discussions and group work.

Corporations make in-kind contributions of state-of-the-art software allowing for optimization of competition vehicles, structures, and components.

Chris Hall and John Helfen with Autodesk conduct an Inventor CAD seminar with Formula and BAJA SAE team members. Ware Lab teams perform complete conceptualization and computer-aided design prior to fabrication of vehicles and structures.

FSAE finite element analysis (FEA) model of rim and tire components show highly stressed regions due to a 3,000 pound force.
Virginia Tech’s Ware Lab is headquarters for many award-winning undergraduate engineering design-build projects.

**Autonomous Aerial Vehicle Team (AAVT)**

AAVT uses extensive computer programming skills to produce an airplane that operates in a totally autonomous flight mode.

Virginia Tech’s AAVT team is comprised of eight senior mechanical engineering students and two graduate student advisors. The overall goals of the team are to design, equip, and test an aerial vehicle (AV) for autonomous flight in the International Aerial Robotics Competition (IARC).

The competition takes place in an indoor environment where the AV must fly into a building, navigate halls and doorways, and choose its navigational preferences based upon light-emitting diode (LED) indicators and sign markings. Once the AV has entered the test environment, the overall objective of the mission is to pick up and exchange one flash drive with another, and exit the environment.

AAVT is comprised of four sub-teams handling vehicle navigation and sensors, vision processing, flash drive acquisition, and stability control. Together, these components will have to communicate with each another on the vehicle and on the ground station as the quad-rotor autonomously navigates the competition environment.

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Michele Shebroe recently served as team leader for BAJA SAE, when they took ninth place out of more than 100 competition teams at internationals. Virginia Tech BAJA has been involved with the Ware Lab since its beginning and consistently scores in the top 20 each year at the SAE regional event. BAJA also participates in Winter BAJA each February at Michigan Tech.

Hard work and mud-soaked test drives are standard operational procedures for the Society of Automotive Engineers (SAE) Baja team. Every year since 1984, Virginia Tech engineering students have designed, built, tested, and raced a new vehicle that can navigate through deep water, steep inclines, mud, rocks, sand, snow, and ice.

The SAE sponsored events judge the vehicles on their maneuverability, suspension, traction, acceleration, design and affordability. The vehicles meet their ultimate tests during grueling four-hour endurance races at annual Baja SAE competitions.

In addition to building rugged all-terrain vehicles, the Baja SAE team must insure its vehicles are safe, easily transported and maintained, fun to drive, and inexpensive.

The Virginia Tech team has a strong history of scoring among top national and international competitors.

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Battery Operated
Land Transport (BOLT)

The 2013-14 BOLT vehicle has a lithium-composite battery stack, controller hardware, and an electric motor. These components are student-designed and built with assistance from Kollmorgen, INC. A motor full-scale prototype was constructed using 3D printer technology to check fit-up with existing vehicle mounting surfaces.

In 2012 the Battery Operated Land Transport team built Virginia Tech’s first 100 percent electric racing motorcycle. The multidisciplinary team competed in the all-electric TTXGP North American Series and finished as the fastest 75 (75 kW output) class bike in the western hemisphere.

VT BOLT was the only academic team participating, competing against all professional teams. For the coming year the team will build upon the foundation laid last year by competing in the unlimited GP class of the TTXGP, pushing the boundaries of electric vehicle technology. The new vehicle will have twice the battery capacity and power compared with last year’s bike.

BOLT employs students from mechanical and electrical engineering as well as Virginia Tech’s business school.

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Students in EngE 1434 tour the CSC to gain a better understanding of how it will meet its goal of becoming a sustainable farming community.

The Virginia Tech Catawba Sustainability Center serves as a living laboratory for the research and demonstration of sustainable practices in land management, agriculture, construction, energy, and economics. The 377 acre Virginia Tech property is in the early stages of renovation and provides an opportunity for Ware Lab students and faculty to be involved in real world problem solving that requires innovative, engineering solutions.

Students in EngE 1434 – Fundamentals of Engineering, who plan to pursue careers in civil, environmental, industrial, and biological systems engineering, visit the site on a regular basis during the semester to gain insight in how to apply engineering design methodologies to help the CSC meet its goals. The importance of site visits and physical measurements are emphasized to students participating in this project. Students are required to present a viable design solution to a current problem associated with the facility and are encouraged to continue capstone related work at the CSC into their junior and senior years of academic study.

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The DBF competition provides students an opportunity to create futuristic aircraft designs using all-electric propulsion systems.

The Virginia Tech DBF Team is a volunteer aircraft design organization. The Virginia Tech chapter of the American Institute of Aeronautics and Astronautics (AIAA) serves as the team’s parent organization since the AIAA sponsors the annual competition. Each year, the team constructs a new radio-controlled model aircraft to complete a given set of missions for the competition. Rules change each year to encourage innovation.

The team participates in several other competitions throughout the year that are sponsored by airline and aerospace companies, professional organizations, and government agencies. All events are aimed at encouraging engineering students to create new concepts for future generations of aircraft.

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http://www.vtdbf.org/
The Formula SAE vehicle is capable of achieving 0 to 60 mph acceleration in less than four seconds and peak lateral forces of up to 1.6 g in turns during competition.

The mission of the Virginia Tech FSAE Team, VT Motorsports, is to conceive, design, and fabricate a high performance formula-style race car with easy maintenance and high reliability that would appeal to the nonprofessional weekend autocross racer.

The Virginia Tech team frequently places in the top ten at the annual international competition sanctioned by the Society of Automotive Engineers. Cars are judged in a series of static and dynamic events: technical inspection, cost, business presentation, engineering design, solo performance trials, and high-performance track endurance. The restrictions on the car frame and engine are few so that the knowledge, creativity, and imagination of the students can be fully challenged.

One car is constructed each year but a two-year design process is used, involving upper and lower classmen. The team consists of over 70 undergraduate students in seven different majors including mechanical, aerospace, electrical, computer, and industrial and systems engineering, as well as marketing and communications. The team is also preparing to compete in 2015 with a fully electric-powered car alongside the combustion vehicle.

Typically, more than 100 vehicles from other colleges and universities around the world participate in this international competition. This year VT Motorsports will be competing in two competitions: FSAE Michigan and FSAE Nebraska.

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Phantom 6 won first place in innovation at the International Sub Race ISU 12, Naval Surface Warfare Center in Carderock, Maryland. This vehicle is the first two-person sub to utilize a side-by-side crew arrangement.

The team’s mission is to design, build, and race a submarine that is propelled solely by human power. The team must size and shape the sub for minimum drag, design and install an efficient power transmission and propeller system, and give the submarine a control system that provides adequate forces without inducing excessive drag. The team is multidisciplinary and includes ocean, mechanical, aerospace and electrical engineers, while also providing opportunities for freshmen to gain practical experience.

This year, the team is finishing the newest sub, Phantom 6, for competition this June.

Phantom 6 is the first two-person (side by side) sub ever built at Virginia Tech. It houses an improved dual linear safety system, advanced controls, and an onboard electronics suite. Through use of a summing differential, power inputs from both pilots are combined and averaged via counter-rotating propeller shafts to allow for maximum power and decreased roll effects. Electronically, Phantom 6 has an on-board computer with attached LED displays. The heads-up display allows for better performance while the computer collects data. This electronics array ultimately led to the idea for an autonomous control system, the major design goal for our next submarine, Phantom 7.

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Hybrid Electric
Vehicle Team (HEVT)

Left: HEVT took first place in the final year of the EcoCAR 2011 international competition using a Chevy SUV and hopes to do the same with a 2013 Chevy Malibu in EcoCAR 2. Right: HEVT team members work to convert a GM Malibu into a plug-in hybrid.

Starting in 1994, engineering students at Virginia Tech have converted cars and sport utility vehicles (SUVs) into fuel efficient, low-emission, hybrid electric vehicles without sacrificing safety, performance, or comfort.

The Virginia Tech team created the world’s first student-designed, fuel cell-powered car and SUV. Since 2000, the team has developed fuel cell and other alternative power systems to prepare SUVs — including a Chevrolet Suburban and a Ford Explorer — for competition in the Future Truck Challenge.

The national competitions were initiated by the U.S. Department of Energy and major U.S. automakers to enlist the help of engineering students in developing cleaner, more fuel-efficient automobiles.

Virginia Tech’s HEVT won the 2011 competition by successfully implementing a hybrid powertrain into a 2009 Chevrolet EcoCAR. This vehicle now uses two electric motors and an E85 engine to allow for efficient driving with fuel economy of 80 mpg. E85 is an ethanol/gas blend that reduces the vehicle’s well-to-wheels petroleum use by up to 74 percent.

The team is currently developing a series-parallel plug-in hybrid GM Malibu to enter into the EcoCAR competition. This challenge is sponsored by the US Department of Energy and General Motors.

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Left: SAE AeroDesign is a student engineering team that participates in the SAE Collegiate East and West Design Series competitions. Right: The SAE AeroDesign team shares the multi-bay area for its construction purposes. The craft uses IC Engine propulsion.

The multi-project bay is a recent addition to the Ware Lab and is used as a space for up to eight different undergraduate student teams from the College of Engineering. Teams work together on a time/space sharing basis.

With generous help from the Student Engineers’ Council (SEC), this bay is now stocked with basic tools and materials and includes lockers for securing parts. Any junior or senior engineering team is welcome to utilize the bay as long as space is available and the project has an engineering faculty advisor. Interested teams need to contact the Ware Lab manager at spangler@vt.edu.

Currently, the following projects along with their main engineering major affiliation and faculty advisor are represented in the multi-project bay:

- **Autonomous Surface Vehicle Team** (Mechanical Engineering, Dr. Alex Leonessa, aleoness@vt.edu)
- **Concrete Canoe** (Civil and Environmental Engineering, Dr. Cris Moen, cmoen@vt.edu)
- **Human Powered Vehicle (HPV)** (Mechanical Engineering, Dr. Saied Taheri, staheri@vt.edu)
- **Lunabotics – Moon Rover** (Aerospace and Ocean Engineering, Dr. Kevin Shinpaugh, kshin@vt.edu)
- **SAE AeroDesign – IC Engine RC Aircraft** (Aerospace and Ocean Engineering, Dr. Pradeep Raj, praj@vt.edu)
- **SailBOT – Autonomous Sailboat** (Aerospace and Ocean Engineering, Dr. Dan Stilwell, stilwell@vt.edu)
- **VTMEC – High Efficiency Motorcycle** (Engineering Education, Dr. Richard Goff, richgoff@vt.edu)
- **VT Rally – Off Road Vehicle Competition** (Mechanical Engineering, Dr. John Ferris, jbferris@vt.edu)
Virginia Tech recently hosted the Virginia Regionals, consisting of colleges in Virginia, West Virginia, and Washington, D.C. The event includes the annual steel bridge and concrete canoe competitions.

Each year the Virginia Tech Steel Bridge Team takes on the challenge of building a scale-sized bridge entirely from structural steel. Team members belong to the Virginia Tech Chapters of the American Society of Civil Engineers and the American Institute of Steel Construction, who sponsor regional and national bridge competitions.

ASCE specifies design rules for the size of competition bridges – typically one-tenth the size of the actual bridge – as well as other parameters such as loading requirements and clearances. Required bridge capacities can be as high as a 2,500 lbs. mid-span load, or the equivalent of a Volkswagen Beetle or Cooper automobile. Teams must construct and load their competition entries at each event and are judged on stiffness, economics, aesthetics, and construction speed.

The team participates annually in the Virginias Regional Conference, the steel bridge competition for engineering schools in Virginia, West Virginia, and Washington, DC. Teams scoring first or second overall qualify to participate in the national competition.

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Ware Lab Outreach

An additional benefit of working at the Ware Lab is participation in public outreach events such as the annual Virginia Tech Center for Enhancement of Engineering Diversity (CEED) Picnic, Kid’s Tech University, Virginia Tech’s STEM Expo in Roanoke, and the College of Engineering’s open house.

Ware Lab projects always make a big impression on young and old alike and these events serve as good recruiting tools for students wanting to be a part of the Ware Lab community. Participation in such events allows team members to develop important public speaking skills and allows them to meet folks who are active in industry. Ford, GM, Lockheed Martin, GE, National Instruments and MathWorks send representatives each year to speak to our students as they work in their bays. These meetings often lead to job offers upon graduation.

Ware Lab teams often partner with other organizations to promote projects. Left: HEVT participates in Sustainability Day on the Virginia Tech campus introducing their new GM Malibu to the campus population. Right: More than 2,000 visitors, including K-12 students, scouts, community college groups, corporate visitors, and academics, take Ware Lab tours each year.

Left: Ford and many other corporate organizations visit the Ware Lab each year to recruit and train students on the latest industry software and hardware. Right: Ford demonstrates its virtual reality programmable vehicle model (PVM).
Ware Lab Corporate and Organizational Sponsorships

Without the generous support of corporate, organizational, and private sponsors Ware Lab teams would not have the resources to participate in national competitions and public events.

Contributions in the form of money, materials, equipment, and software allow Ware Lab groups to produce state-of-the-art competition vehicles, structures, and components.

In addition to monetary and in-kind support, Ware Lab teams often interact with seasoned design engineers from industry who contribute their time working face-to-face with students.

Our corporate and organizational sponsorships continue to grow and include the following:

A123
Altria
Areva
Associated Power
Autodesk
Baker Hughes
Black & Decker
Ford
General Motors
Goodyear
Honeywell
Ingersoll Rand Club Car
Lockheed Martin
MPT
Nucor
OG Racing
Parker
PCB
Siemens
Sign Systems Inc.
MathWorks
U.S. Department of Energy
Virginia Tech Student Engineers’ Council
Westinghouse
Private sponsorships are essential in helping Ware Lab cover operational expenses and in allowing teams to receive yearly stipends that serve as important seed money. These funds help teams recruit new members and purchase equipment and services necessary for completion of project deliverables.

Our private contributors who have created permanent endowments, allowing projects a continual source of seed money are:

• John and Elizabeth Donehower
• Marvin and Susan Johnson
• Virginia Tech Student Engineers’ Council

The Ware Lab teams travel to competitions and public relations events in a GM Sierra and 36’ Gooseneck Vintage Trailer donated by General Motors and Baker Hughes.
For more information about the Joseph F. Ware, Jr. Advanced Engineering Lab, go to: www.eng.vt.edu/warelab/

The Ware Lab is located diagonally across from McBryde Hall and directly across from the Kelly Building on the engineering quad of the Virginia Tech campus.

For more information on the Ware Lab’s location on the Virginia Tech main campus go to: http://www.vt.edu/where_we_are/maps/index.html

For important parking information go to: http://www.parking.vt.edu/

Virginia Tech does not discriminate against employees, students, or applicants on the basis of age, color, disability, gender, national origin, political affiliation, race, religion, sexual orientation, or veteran status. Anyone having questions concerning discrimination or accessibility should contact the Office for Equity and Access.