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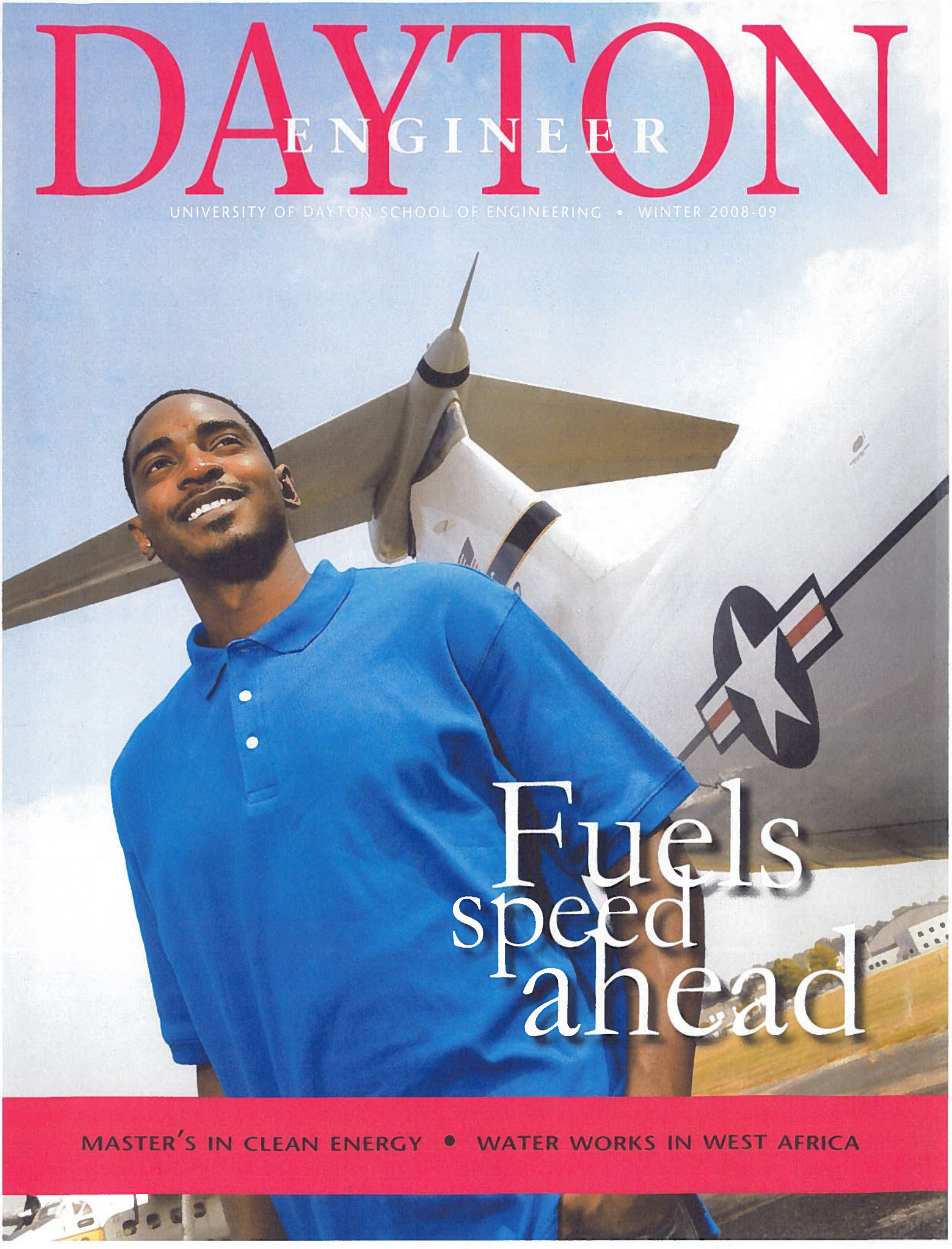
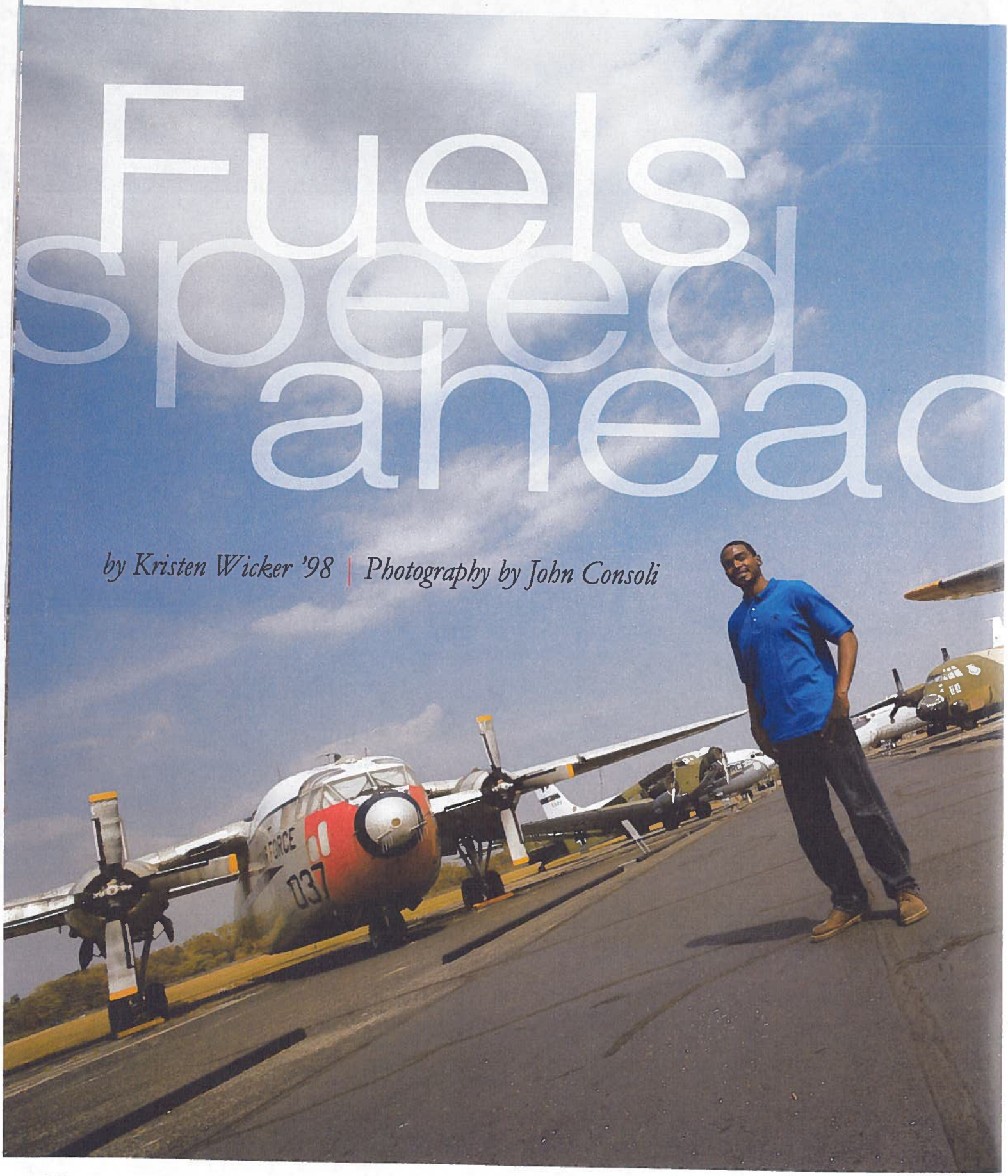


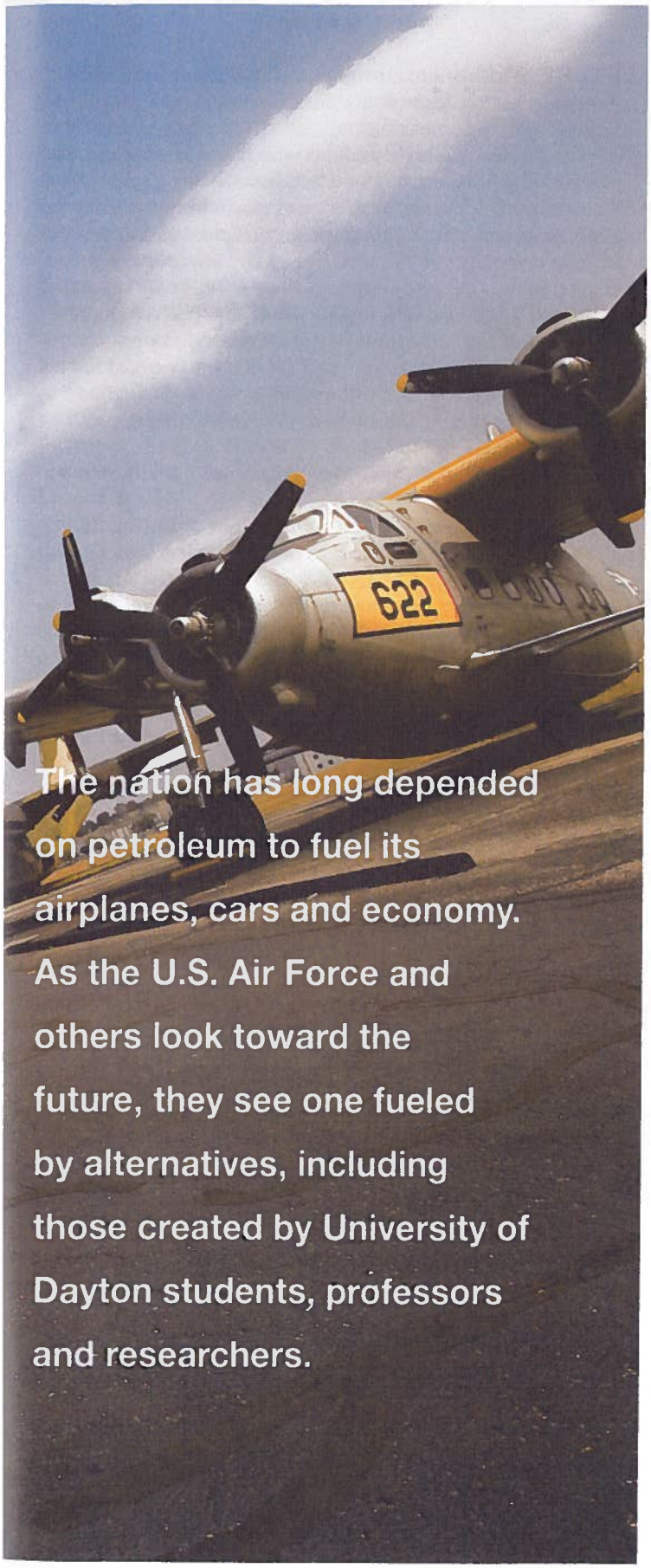
Fuels speed ahead

MASTER'S IN CLEAN ENERGY • WATER WORKS IN WEST AFRICA

Fuels speed ahead

by Kristen Wicker '98 | Photography by John Consoli





The nation has long depended on petroleum to fuel its airplanes, cars and economy. As the U.S. Air Force and others look toward the future, they see one fueled by alternatives, including those created by University of Dayton students, professors and researchers.

"Energy is the next big thing," UD graduate student Kevin Taylor said. "You can take that to the bank."

Indeed, Taylor's sentiments echo those of many on campus — and beyond. High prices at the pump may have heated the national discussion about energy use, but faculty researchers and students have been examining this issue for years. Now, their work is more significant than ever.

"We have a real problem in terms of energy security because 70 percent of the petroleum we use is imported from other countries," said Binod Kumar, distinguished research engineer in the metals and ceramics division of the University of Dayton Research Institute and professor in the mechanical and aerospace engineering department. "I have difficulty when I try to fill my tank, so how about others who are earning the minimum wage? We have a real societal problem, and we cannot postpone solving it."

Something else you can take to the bank: UD will be a major player in the solution.

"The central challenge of the 21st century is to make our society sustainable, and the single most important issue within that challenge is energy use," said Kelly Kissock, professor in the department of mechanical and aerospace engineering. "UD is a national leader in this field."

The University holds this leadership position in part because of the opportunities it gives undergraduate and graduate students to participate in research.

"I don't think anywhere else can you find this combination of working on a military base while attending a top-tier university that specializes in engineering research," said Taylor, who works in the Propulsion Directorate at the Air Force Research Laboratory on Wright-Patterson Air Force Base. "The opportunity to work in a government lab and work with researchers who have decades of experience in this field is priceless."

Coal — only different

Taylor works on projects related to the Assured Aerospace Fuels Research Facility, the nation's first federal research facility aimed at enabling new feedstocks for jet fuel. Funded with a $10 million grant from the Air Force Research Laboratory, the facility also will support research into developing more efficient and environmentally friendly fuels.

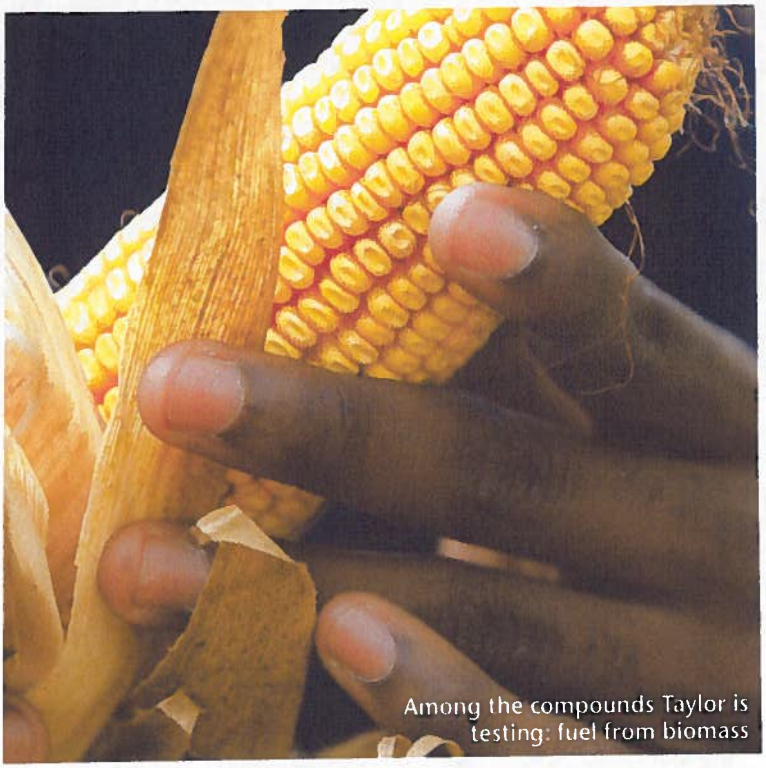
"The Air Force funding demonstrates the importance of this research and maintains Ohio's leadership in this field," said Dilip Ballal, head of UDRI's energy and environmental engineering ▶

Left: **Kevin Taylor hopes his research on jet fuels can help make Air Force dependency on foreign fuel sources a thing of the past.**

division and director of the University's von Ohain Fuels and Combustion Center. "This work is a matter of national security for the U.S. Department of Defense, one of the biggest consumers of energy, especially because of our current engagement in Afghanistan and Iraq."

The research being conducted at the facility will help create a domestic source of fuel using coal and biomass, both of which are readily available in the United States. The Fischer-Tropsch process used to create the new clean, efficient diesel and jet fuel (see sidebar) was first developed by German scientists in the 1920s, but Ballal and his team are perfecting the process.

The Air Force needs a nonpetroleum-based fuel that's also a drop-in replacement for current fuels, Taylor said. "We need to find fuels that burn efficiently and clean, but also meet the specifications of existing aircraft and are economically feasible."



Among the compounds Taylor is testing: fuel from biomass

It makes sense such research would take place in Dayton. In addition to the location of Wright-Patterson and Ohio's large stockpile of coal, UD's fuels and combustion program was founded 25 years ago, and since then the University has pioneered numerous research projects for the U.S. Air Force, Ballal said.

"We have the No. 1 expertise in the nation in jet fuels," he added.

The partnership with the Air Force, which encourages students to participate in research, also allows the University to offer scholarships and fellowships. In addition, the state of Ohio is creating an endowment to support a distinguished research scholar in the von Ohain Fuels and Combustion Center.

"Energy and fuels will be important to us for many years to come, so this is a tremendous opportunity for graduate students," Ballal said. "Our students who acquire training in areas of fuel, combustion, environmental pollution and energy receive a tremendous career boost and are picked up almost immediately by large companies."

Yet it's not only graduate students who have the opportunity to participate in this research. In addition to Taylor, Zachary Sander, a junior mechanical engineering major from Indianapolis, works closely with Steven Zabarnick, group leader in fuel science at UDRI and professor in the mechanical and aerospace engineering department.

"I attended a three-day design review of the (Fischer-Tropsch) reactor, worked with blueprints of the system and ran tests on certain fuels and hydrocarbons," said Sander, who worked full time at UDRI last spring and will work there again during the 2009 spring semester. "I already have experience with research and how it's designed."

Zabarnick noted such experience is extremely valuable for future engineers.

"Students are getting in on the ground floor, acquiring the engineering knowledge they need to become leaders in designing and building these plants," Zabarnick said. "While the Air Force is interested in this program for jet fuels, it's really developing this technology in the United States so our nation is a leader in fuels research."

Battery for life

For nearly 20 years, Binod Kumar has been examining another energy conundrum: how to efficiently and effectively store energy.

Batteries and fuel cells are devices for energy storage and power generation, respectively, and students examine them in Kumar's laboratory. They test the longevity of existing batteries and fuel cells, but their work also has been crucial in the development of a new type of energy storage: lithium air batteries.

Kumar and his team have developed a ceramic membrane that makes these batteries top performers (see sidebar). Indeed, the lithium air batteries with which Kumar has been working already pack a whopping 3,000-watt hours per kilogram — enough to power a cell phone for 250 hours.

"It's more efficient to extract energy from lithium than gasoline, and lithium is as energy dense as gasoline," Kumar said. "You could power a car with a lithium air battery — that's not a farfetched idea. We can even think much bigger than that."

Now, Kumar and his team are working on creating a marketable lithium air battery and looking for a company to manufacture it.

Another goal is finding a renewable power source that can work in conjunction with lithium air batteries. Take that car, for example: Kumar imagines attaching a solar cell on the car's roof that, during the day, would recharge the lithium air battery running the car — creating a vehicle that wouldn't use an ounce of gasoline.

Waste not, want not

University faculty are tackling other pieces of the energy puzzle, too, including enhancing energy efficiency and the development of renewable energy sources, such as wind power.

Kelly Kissock also serves as director of two University of Dayton centers: The Industrial Assessment Center, which helps mid-size manufacturers reduce their energy usage, and the Building Energy Center, which helps improve the energy efficiency of buildings.

"I teach a class in energy-efficient buildings, which is the most popular elective we offer," Kissock said. "Students like this class, and they're getting jobs in this field."

Students have a valuable mentor in Kissock. Currently, he's working with Dayton-area city governments to examine the energy efficiency of their buildings. Kissock has developed energy simulation software that helps with these and similar energy evaluations. In addition, through the UD Industrial Assessment Center, he's worked with more than 780 manufacturers since 1981 — saving clients an average of $100,000 per year on their energy bills and reducing their annual energy use by 10 percent. Kissock also has conducted studies with such organizations as Dayton Power & Light to examine the feasibility of wind power.

"UD is a national leader in this field," Kissock said. "We're educating the next generation of engineers and giving students a chance to apply what they learn in class. As a result of these experiences, these students will help their clients and employers save energy. Imagine the amount of energy that will be saved during the course of their careers."

Much potential for energy savings also exists in faculty research. Kevin Hallinan, chair of the department of mechanical and aerospace engineering, and a graduate student are examining how to harvest waste heat using thermoelectric devices, which are ceramic plates. They're working to create materials that will recover excess heat and transform it into electricity.

"Any inefficiency is heat waste," Hallinan said. "We're trying to recover that waste wherever it exists."

In addition, associate professor of mechanical and aerospace engineering Aaron Altman is in the beginning phases of a project researching vertical axis wind turbines. While these turbines are rare, they generate the most torque, allowing them to effectively power pumping stations.

"We want to develop something so people without resources can use these wind turbines to satisfy some of the most basic needs, such as clean drinking water," Altman said. "This could be very cost effective and used in developing countries."

Other faculty members are engaged in energy-related research, such as developing infinitely rechargeable supercapacitors for energy storage and cost-effective wind turbines that generate energy in a variety of wind conditions.

All this means UD faculty, students and alumni are sure to be part of the energy solution.

"I've been working in this field the last 20 years and know how important it is," Kumar said. "If we have the proper priority and funding, and if we support creative people coming up with innovations, we can lick this problem in the next 20 years."

Read about the energy projects of fellow graduates at http://engineer.udayton.edu.

BREATHING LIFE INTO BATTERIES

In a typical battery, once the reactants stored inside are used up, the battery dies. However, in lithium air batteries, one of the reactants is oxygen, and these batteries are designed so oxygen continuously runs through it — creating a battery with a much longer lifespan.

"That's why we call it the 'ultimate battery,'" said UDRI researcher Binod Kumar. "As long as you have a flow of reactants, the battery works."

Lithium is also a great source of energy, he explained. A metal, it's easily stored. It's rechargeable and nontoxic. It easily can be mined, as it's found dissolved in lake water.

However, lithium also is highly reactive. That's where Kumar and his research team step in: They've developed flat, round lithium air batteries — similar to those found in a watch, but with small holes on one side — that use a ceramic membrane to prevent corrosion and control the lithium's reaction. This ceramic membrane makes these batteries high performers.

RECIPE FOR COOKING UP A NEW FUEL

The coal-biomass to liquid process, or CBTL — used to create a new clean, efficient fuel for the U.S. Air Force — will be the centerpiece of the Assured Aerospace Fuels Research Facility. The first two phases of the project, which primarily involve synthesis gas reforming and fuel upgrading, are under way at Wright-Patterson Air Force Base. The third phase, which includes the construction of a coal and biomass gasifier that will produce synthesis gas for the new fuel, is being studied.

The CBTL process, of which the Fischer-Tropsch process is part, works like this:

- Coal, or a mixture of coal and biomass (which includes such products as algae and switch grass), is gasified in a combustor to produce synthesis gas.
- The synthesis gas, which consists of carbon monoxide and hydrogen, is passed through a Fischer-Tropsch reactor to create a nonpetroleum-based solid wax.
- The wax is further reacted to create alternative transportation fuels, including diesel and jet fuel.

"The Air Force uses 2.7 billion gallons of petroleum-based jet fuel a year so if we reduce that by 50 percent, that's a big improvement," said Dilip Ballal, the Hans von Ohain Distinguished Professor of Mechanical and Aerospace Engineering. "We want to demonstrate that we can produce nonpetroleum-based synthetic jet fuel in an efficient fashion and also keep the carbon footprint down."

Graduate student Kevin Taylor's research helps ensure the fuels being developed are compatible with the Air Force's existing fleet. He examines the chemical content of fuels and how they affect fuels' properties.

The work that will take place at the Assured Aerospace Fuels Research Facility has big-picture implications. Commercial airlines consume even more fuel than the Air Force does and are keeping close tabs on this research.