

The Product is the People

Government-funded, university-based centers of excellence cultivate engineering talent as they investigate promising flight technologies.

By Frank Colucci

The Vertical Lift Research Centers of Excellence (VLRCOEs) at the Georgia Institute of Technology, the University of Maryland and the Pennsylvania State University are rotorcraft laboratories and talent factories for US government labs and industry. Georgia Tech center director Dr. Marilyn Smith explained, “The VLRCOE is a workforce development program. We do research — we do very good research — and things come out. What we really do is we create engineers and engineering scientists who are able to build and analyze the next vehicle and support warfighters. Our number one product is the people.”

Penn State University VLRCOE director Dr. Edward Smith calculates that since 1996, his Center has graduated around 200 engineers to work in vertical flight industry and government sectors. Some research alumni went on to fill faculty positions in the VLRCOEs themselves and partner universities. Smith said, “The specialized training has been pollinating the faculty not just at these three schools, but all over the place.”

University of Maryland (UMD) aerospace engineering associate professor Dr. Anubhav Datta noted the UMD VLRCOE in the Alfred Gessow Rotorcraft Center has a long working relationship with the US Naval Academy, for instance. “Many of their faculty are our former students,” he said. Other graduates of the UMD VLRCOE are researching air-launched uncrewed aircraft systems (UAS) at Texas A&M University. Historically the UMD Center advised 50 to 60 student researchers a year. With declining government funding (see “Workforce: Winning the War for Talent,” *Vertiflite*, May/June 2021) the VLRCOE itself now supports only 10 students directly. Industry grants from Lockheed Martin and Boeing double that number, and “self-supported” researchers sponsored by the US Army and Navy bring the current total to 30.

Due to re-compete for government funding in 2026, the five-year VLRCOE programs are competitively selected and sponsored by the US Army’s Combat Capabilities Development Command (DEVCOM) Aviation & Missile Center (AvMC), the Office of Naval Research (ONR) and the NASA Aeronautics Research Mission Directorate. Each university leverages unique facilities and relationships to pursue proposed research — Penn State alone collaborates with around 10 different rotorcraft research centers around the US. The impact of Army, Navy and NASA funding is amplified by the schools themselves and grants from



The Penn State VLRCOE researchers use their third-generation moving base simulator to evaluate flight control laws. (Penn State University)

the Federal Aviation Administration (FAA) and industry. Ed Smith noted the \$1.5–1.8M Army/Navy/NASA investment in each VLRCOE typically funds 13 to 14 research tasks. Penn State ultimately turns the government seed money into \$8–9M of research activity. “It’s way more than 12 or 15 projects. It’s many times that with different sponsors.”

Georgia Tech likewise leverages the VLRCOE momentum to conduct broader rotorcraft research. Marilyn Smith counted, “For every VLRCOE task, we’re got externally three or four other tasks outside the VLRCOE.” Georgia Tech investments have long matched government VLRCOE funding one-for-one despite rising costs. “It’s hard to do that,” said Smith. “We’re a state university and don’t want to increase tuition. We have been a true partner in my opinion.” The Georgia Tech aerospace engineering department expects to open a new building in 2027 or 2028 and continues upgrades of wind tunnels, simulators and other facilities used by VLRCOE researchers. The school is also growing its teaching staff. “We’re hiring faculty like crazy,” observed Smith. “Aerospace here at Georgia Tech is growing. It’s a great time for burgeoning academics to send us resumes.”

University of Maryland

The VLRCOEs define their own research specialties and dedicate faculty and facilities to government-sponsored five-year tasks. Anubhav Datta at Maryland explained, “We work on three major thrust areas: computational aeromechanics with focus on structural dynamics; wind-tunnel testing with focus on high-speed tiltrotors and compound helicopters; and electric aviation with focus on eVTOL” — electric vertical takeoff and landing aircraft. UMD high-performance computing research sponsored by the



University of Maryland student researchers work on the scaled tiltrotor rig in the 8-by-11 ft wind tunnel to learn how to build proprotor blades and hubs. (University of Maryland)

Army and Boeing aims at extra-high-fidelity simulations and 3D modeling. The objective, according to Prof. Datta, is “to take advantage of high-performance computing to test and certify aircraft before a single part is built.” Current VLRCOE research tasks teach students basic aerodynamics, structures, materials and rotor blades; computational fluid dynamics; and haptic control feedback, all with application to future rotorcraft.

High-speed tiltrotor research sponsored by the Army and ONR at the UMD VLRCOE aims at convertible aircraft faster than today’s V-22 Osprey. “The objective there is to break the whirl-flutter barrier and reach 450 kt [830 km/h],” said Datta. UMD’s tiltrotor lab is unique in the United States and currently has a 1/8-dynamically scaled V-22 right wing and proprotor. The test rig enables student researchers to change the wing, proprotor blades and hub to model hinged Bell-style tiltrotors or hingeless eVTOL concepts. Datta said, “The students learn how to build blades, about composites, how to build hubs.” The electrically-driven tiltrotor rig also gives students insight into distributed electric propulsion. “They’re learning what it means to have an electric motor in there.”

Another effort with NASA and UMD internal funding continues work on Mars coaxial helicopters (see www.vtol.org/mars). Datta said, “The objective there is to build larger, more capable helicopters for Mars to carry out science missions, building on the success of Ingenuity.” Maryland researchers can also use the coaxial rotor rig at the University of Texas at Austin to take high-precision noise measurements on new earthly helicopter configurations.

Funding from the government and Lockheed Martin supports haptic feedback studies at UMD meant to give human pilots cues from uncrewed aircraft via augmented reality. According to Datta, “If you want to fly helicopters from far away, you don’t get a feel of what the aircraft is actually experiencing. There’s new technology now to feed it back into the body of whomever is flying it. Haptics and augmented reality is a big, hot area.”



UMD researchers tested a high-speed compound helicopter model in the Glenn Martin wind tunnel. (University of Maryland)

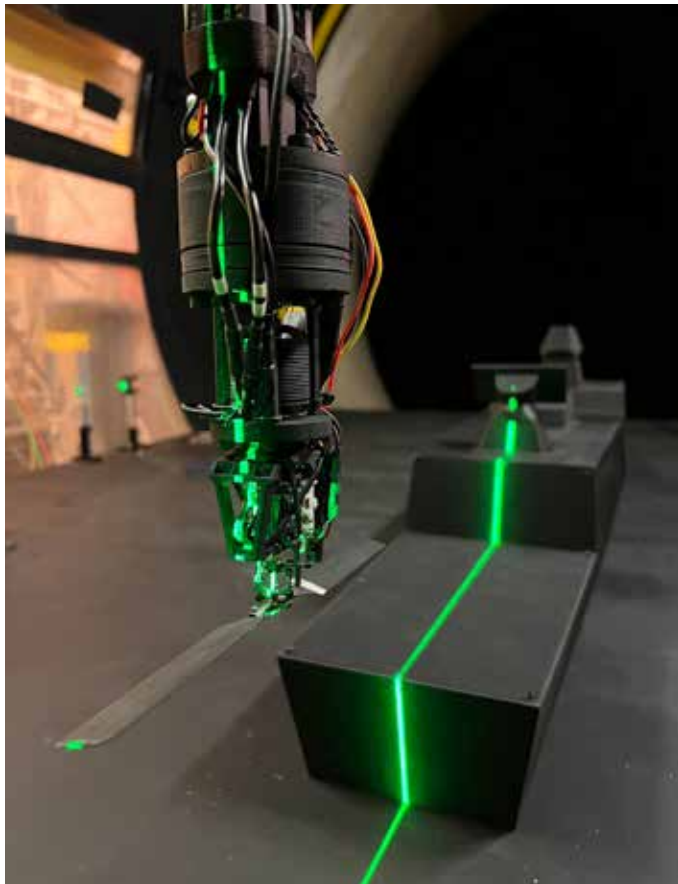
Distributed electric propulsion research at the Maryland VLRCOE uses a new hybrid-electric aviation lab with interchangeable engines, generators and rotors to teach students how hybrid drives, hydrogen fuel cells and other power systems work. The lab’s hydrogen fuel cell area aims to extend the range of eVTOL vehicles and enables researchers to fly small-scale drones connected to benchtop power sources. UMD researchers can also use the battery fabrication facilities in the Army Research Lab in nearby Adelphi, Maryland, to test different power chemistries. “The focus there is lithium-sulfur chemistry,” said Prof. Datta. Sulfur is notably cheaper and more available than lithium for limited-life military applications. “The goal is twice as much energy as lithium-ion but with the same power.”

Georgia Tech

Advanced air mobility (AAM) poses more challenges as lightweight aircraft encounter winds, clear-air transients and transient vortices between buildings. “We need to predict what that environment is without having to model it,” said Georgia Tech VLRCOE director Marilyn Smith. “We want a representative environment, but it doesn’t have to be exact.” Georgia Tech student researchers and faculty are developing a real-time representative environment model for computational fluid dynamics (CFD), flight simulations and other aircraft assessments near urban obstacles.

“The key here is can we non-dimensionalize things so you can use a single model, if you will, depending on its size and height and width with respect to where you’re flying... We’re not going to build a model for every building, but something you can scale-up,” Smith explained. “The end product is first this reduced-order model, a near-real-time model that you can use as an input. You put in the shapes, and as you fly [the vehicle] through a simulator or a computer code of any level, it will give you representative velocities in each component direction as they change with time. It’s as through you’re flying through it.”

Other computational/experimental projects are working on multirotor interactions, including the transition from rotor to



Georgia Tech researchers investigate ship-rotor interactions in the Harper wind tunnel. (Georgia Institute of Technology)

propeller propulsion for tiltrotors and AAM vehicles. VLRCOE associate director Dr. Juergen Rauleder works on the physics of unconventional vertical lift designs and ship-rotor interactions. Marilyn Smith says the end product will be a high-quality database of experiments that can be used to validate design codes and understand new designs. “Can we capture interactions to design these multi-rotor vehicles more accurately?”

The Georgia Tech VLRCOE typically hosts 20–22 graduate students and four to six government researchers. Smith noted, “Most are from aerospace engineering, but they go across all the same disciplines as their faculty members — flight controls, human factors, structures, aerodynamics.” Master’s candidate Tarun Golla recently earned an award from the Georgia Tech chapter of Sigma Xi — the scientific research honor society — for an innovative approach to predicting flutter in unconventional aircraft designs. Marilyn Smith explained, “If you’ve got these vehicles with wings or arms and offset rotors or tilt rotors, in certain conditions... the blades going around the hub take a circular or oval path. It’ll start going unstable right there.” Georgia Tech also collaborates with the University of Michigan on whirl flutter, and VLRCOE research aims at modeling techniques to aid in aircraft design and analysis.

The Georgia Tech VLRCOE draws on new and historic research facilities. The 7-by-9-ft (2.1-by-2.7-m) Harper Wind Tunnel built in the 1930s has been renovated with a new drive motor and new windows for particle image velocimetry (PIV). Depending on

funding, an all-new tunnel in the coming engineering building will be about the same size but provide more capability. A motion-based simulator coming online this year will support vertical lift research and teaching. New Georgia Tech labs are being designed platform-agnostic to explore AAM and other designs.

Georgia Tech and Embry-Riddle Aeronautical University (ERAU) researchers collaboratively look at ship-rotor interactions using two different wind tunnels, the Embry Riddle facility with rotors static with respect to a deck and the Georgia Tech tunnel capable of dynamic approaches to the model ship. “Together, we’re kind of pulling everything together,” offered Marilyn Smith.

Penn State

The VLRCOE at Penn State University (PSU) started in 1996, after UMD and Georgia Tech, with only modest funding for six or seven early research projects. Director Dr. Edward Smith observed, “Each time we’ve re-competed — every five years — our piece of the pie went up, and the space allocated here on campus went up.” With funding from a variety of sources, the Penn State VLRCOE today has around 70 student researchers and a distinguished list of graduates filling government, industry and academic leadership positions.

The Penn State VLRCOE collaborates most closely with the University of Tennessee, Knoxville; the University of California, Davis; and Auburn University in Alabama. Ed Smith said, “At all three, you’ll hear about aeromechanics; that includes aerodynamics, vibration control, flight control simulation and acoustics.” The three primary partners tie in 10 or 12 schools in total.

Penn State researchers have access to unique facilities, including a new high-pressure wind tunnel at University Park Airport. The new tunnel with its large pressure vessel can test rotor system and fuselage models at high Reynolds numbers. Flight control and simulation researchers use a third-generation moving base simulator now with the Bell 609 mockup cabin, spherical screen visual system and six projectors. Company and military test pilots use the device to evaluate flight control laws alongside VLRCOE students and faculty.

Also unique to Penn State is adverse environment rotor research into icing, erosion and strong winds based on AERTS — the adverse environment test stand. AERTS turns rotors up to 10 ft (3 m) diameter inside an icing cloud test chamber to study the physics of ice accretion. The test stand has evaluated ice protection technologies, including advanced heaters and coatings, pneumatic inflatable boots without troublesome slip rings and non-thermal ultrasound systems. “We want low power and highly durable solutions,” said Smith. AERTS has been used for 20 years and in the next year to 18 months will move to a new PSU engineering building with a test chamber three times larger.

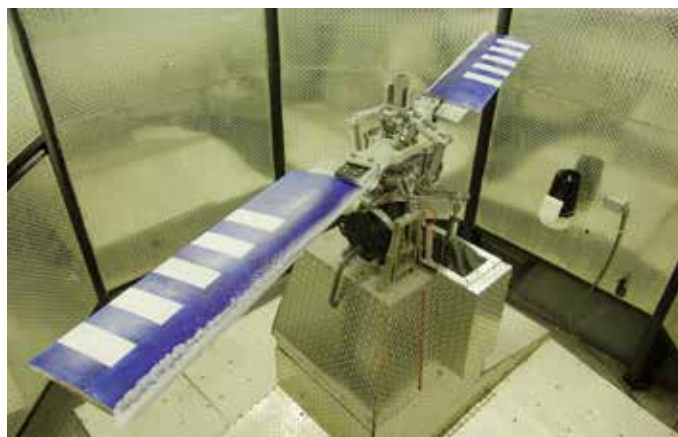
The new building will also have an anechoic chamber three times the size of current test areas and instrumented for better noise measurements. PSU investigations of interior and exterior acoustics are supported by the Army, Navy and NASA. Smith explained, “We’re paying attention to reducing the interior noise in

the cabin — that's been supported by the Navy and NASA over the years. We're trying to come up with lightweight composite structures that have low noise and high strength."

Composite panels have undergone noise transmission loss experiments at Penn State and NASA Langley that simulate airborne noise from rotor pressure fluctuations and structure-borne noise from high-frequency gear vibrations. Acoustic black holes taper structures and allow for energy absorbing damping materials on the panels. Smith said, "You come out with a panel that doesn't add hardly any weight, but is considerably quieter." Researchers targeted 3–4 dB noises reductions but have measured 5–6 dB improvements. "That project has a lot of momentum right now and a lot of relevance to the eVTOLs."

Also relevant to eVTOL aircraft, PSU researchers are working on aeroacoustic predictions, noise-reducing changes in flight paths, and quiet rotor design. "We do a lot of scale model testing and flight testing of larger scale vehicles in anechoic wind tunnels," noted Smith. Small-scale tests of rotor-rotor and rotor-wing interactions, exotic rotor planforms and tip shapes, and phasing of multiple rotors have made test articles 5–10 dB quieter than conventional helicopter rotors.

Ed Smith noted, "At our center, one of the things that's unique is the drive systems and propulsion lab. I don't think we have any real counterpart in gearing, transmissions, driveshafts." A pericyclic transmission tested in December 2023 at the Army's Aberdeen Proving Ground was designed to achieve high reduction ratios



The Penn State AERTS — adverse environment test stand — turns rotors up to 10-ft (3 m) in diameter inside an icing cloud test chamber to evaluate ice protection technologies. (Penn State University)

with a single gear stage and provide low interior noise. According to Ed Smith, the technology could be an enabler for variable-speed applications, such as hybrid-electric rotorcraft. VLRCOE faculty and students working with Boeing, NASA Glenn, ONR and Army Aberdeen advanced the transmission from patent-level to prototype technology. The effort involved gear-maker Gleason; bearing maker Timken; and rotorcraft transmission developers Boeing, Bell and Sikorsky. Though most VLRCOE investigations aim at fundamental (6.1-level) research shared in theses and journal papers, Ed Smith acknowledged, "We like working with industry to get problems more practical."



Illuminating the Path Forward

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