Schrage at Forum 74 in May 2018. (VFS photo)

Dr. Daniel Schrage

Director Emeritus
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In 35 years of teaching and research at Georgia Tech, Dr. Dan Schrage has advised more than 50 doctoral and 150 masters-level students, including current US Army vice chief of staff Gen. James McConnville and Aviation Development Directorate director Dr. William Lewis. "Georgia Tech has attracted by far more military students than any of the other rotorcraft centers of excellence [RCOEs]," Schrage observed. (The other centers are currently the Pennsylvania State University and the University of Maryland.) "Also, many of our civilian students attracted to the RCOE/Vertical Lift Research Center of Excellence [VLRCOE] have become industry leaders. Almost all of them have taken my rotorcraft design courses."

Schrage explained, "I've tried to continue to use vertical lift design and multidisciplinary design optimization as the integrating function for emerging technologies in autonomous vehicles, advanced configurations and now hybrid and all-electric VTOL [vertical takeoff and landing] aircraft." The Georgia Tech VLRCOE supplements its own distinguished faculty with renowned vertical flight educators and researchers from Iowa State University, the University of Michigan, Ohio State University, Purdue University, the University of Texas Arlington and Washington University in St. Louis. According to Schrage, "Our areas are aerodynamics, aeroelasticity, flight dynamics and controls, structures and materials. We're also strong in propulsion — the rotorcraft centers have never had propulsion as a separate discipline."

Schrage noted, "Every year for the last five, ten years, I've tried to get the Army to have the three rotorcraft centers work on a multi-disciplinary design integration effort, preferably rotor hub design, because I think that would be beneficial. If you look at what we and Maryland and some of the other schools have done in vertical flight design, it's really comparable design analysis to what the government and industry can do."

The original Georgia Tech RCOE (today's VLRCOE) began using the American Helicopter Society (today's Vertical Flight Society) student design competitions in 1984 as a means to integrate vertical flight disciplines and set the stage for a world-class student design competition. The current Georgia Tech GoFly team plans to fly the Project Hummingbuzz distributed electric propulsion demonstrator early next year. "It's a shrouded, contra-rotating prop," explained the VLRCOE director. (Unlike a ducted fan, the propeller diameter is greater than the length of the shroud.) "There are a lot of people looking at this for their bigger vehicles. The key thing is [that] distributed electric propulsion lets you fly with a whole lot of open props, fans. The quad-rotor is very good for small vehicles, but when you start growing it, yaw control becomes a big problem, and you need variable pitch control. People also don't like open rotors. We have people who do a lot of basic research in coaxial props, coaxial rotors, shrouds, and ducts, but you've got to get them to look at it with an integrated design function."

VLRCOE research has advanced aerospace systems design, integrated product and process development, flight mechanics and controls, multidisciplinary design optimization and the understanding of rotor dynamics and aeroelasticity. "We've done a lot of really good technologies, but the users are still reluctant to integrate these technologies," Schrage observed. "There's always a little competition between us and the government labs doing 6.2 [applied] research. They think, 'You're still just basic [6.1] research.'"

Schrage in Vietnam with his Bell UH-1 Huey (Family photo)

Real-World Rotary-Wing

Dan Schrage graduated from Mater Dei High School in Breese, Illinois, drawn to engineering. He recalled, "I was more interested in being an engineer because when I was in high school, I really liked math and science." Schrage applied to the US Military Academy in West Point, New York, but won only a spot on the first-alternate list. "My father was a high school teacher and coach, so we weren't very wealthy, and to pay full college tuition somewhere would have been difficult. I attended a small college, Quincy College, now Quincy University, on a basketball and baseball scholarship. I was a math major to keep the door open to maybe becoming an engineer, which was why I left Quincy College after one year."

With a slot at West Point, Cadet Schrage tried specialist Army branches in summer camp. "I decided I wanted to be an aviator. Aviation was not then a branch, so I had to pick a branch — Artillery — and serve for at least a year before I could go to flight school." On graduation, the new second lieutenant joined an Honest John (nuclear-capable, surface-to-surface) missile battalion in Munich, Germany, and then in nearby Augsburg. "These were pretty big missiles. It took a crane to mount the warhead on a rocket motor and put it on a five-ton launcher. Then we had to drive them two or three hours to Ansbach, Germany, and point them toward the Fulda Gap. Things changed pretty rapidly when the Russians put five or six divisions in Czechoslovakia in 1968. All of a

sudden, they were three hours away by tank. It took us about six hours to get into position with a nuclear weapon."

A subsequent return of forces to Germany (REFORGER 1) exercise underscored the limits of ground mobility. "We were on the German countryside, and it was unusually mild. Those long-wheelbase, five-ton trucks I had got stuck all the time. I said, 'Wait a minute. There's a third dimension here: there's aviation.' I had good experience there that aviation was essential in modern warfare."

Dan Schrage started flight school at Fort Wolters, Texas, and Fort Rucker, Alabama, in March 1969. He graduated to a combat tour flying Hueys with the 162nd Assault Helicopter Company at Can Tho, South Vietnam. "I flew both the UH-1D and UH-1H and led combat air assault missions. After three months as the 1st Lift Platoon Leader, I was asked to take over the gunship platoon and flew UH-1C gunships.

"I was promoted to be the S-3 [operations officer] for the 13th CAB [Combat Aviation Brigade]. I flew the OH-58A/C and also flew the OH-6A scout helicopter with C Troop, 16th Cavalry. The 13th CAB commander, Lt. Col. Bob Sauers, asked me to do an in-country evaluation of the two scout helicopters in low altitude, nap-of-the-earth combat operations. He had been involved in the second Light Observation Helicopter [LOH] competition and was very upset, as were most Army combat aviators, with the selection of the OH-58 over the OH-6 in 1968.

Schrage plans to continue to work on the Hummingbuzz concept beyond "retirement" from teaching (HUMBUZZ LLC image)

"Our LOHs would fly in and around trees and everything else. It was evident there that the OH-58 wasn't near as responsive as the OH-6 was. The two-bladed teetering rotor is a great helicopter, but over the years, there were lots of problems with teetering rotors, including potential mast-bumping. If you fly close to the ground like nap-of-the-earth (NOE), or fly around trees, then pull up and push over, and flapping gets beyond about 10 degrees, your rotor contacts the shaft. It doesn't mean the shaft is going to come off right away, but you'll get some fatigue damage that's going to fail some flights later. Out of Vietnam experience, the UTTAS [Utility Tactical Transport Aircraft System competition that resulted in the UH-60 Black Hawk] maneuver was required to show you could do a pull-up and a push-over safely in NOE. That became a critical maneuver for both the UTTAS and the AAH" — the Advanced Attack Helicopter competition which gave birth to the AH-64 Apache.

Critical Collaborations

The UTTAS and AAH competitions started in 1972 and 1973, respectively. Dan Schrage earned his master's degree in aerospace engineering at Georgia Tech and arrived at the US Army's Aviation Systems Command (AVSCOM) in St. Louis, Missouri, in May 1974. "With the AAH and UTTAS prototypes nearing completion of design and analysis and component testing, I began a major, accelerated effort to become Army aviation's vibration, dynamics and aero-elasticity evaluator and trouble-shooter." All four helicopters types — two each competing in the Army UTTAS and AAH fly-offs — had vibration problems, in part because of the short main rotor shafts needed to fit Air Force transports.

Schrage recalled, "The nice thing was the collaboration between the government and engineers at that time was really good." With Army input, both Sikorsky with its YUH-60 UTTAS and Hughes with the YAH-64 AAH deviated from air transportability requirements and raised their main rotors to alleviate vibration and improve performance. Boeing's YUH-61 vibration fix failed and added weight to its UTTAS contender. Schrage noted, "I wrote the technical red flag that caused Sikorsky to win and Boeing to lose." He added, "I really believe to this day, if they'd raised the rotor they could probably have won the UTTAS contract."

The Apache also suffered vibration problems at high speed traced to its modified T-tail. "We really helped redesign that tail with a stabilator," recalled Schrage. "That's the way you solve problems. You've got to do it in a collaborative way. What we had back then was clear-cut integration between the user and the developer. In 1983, I spent six months at Fort Leavenworth [in Kansas] as the chief scientist for the combined arms center, and I had a really good rapport and understanding of the operational side."

Prior to becoming an Army reservist in 1978, Dan Schrage earned his doctorate in mechanical engineering from Washington University under Dr. Dave Peters using Floquet Theory to predict helicopter rotor loads and stability based on the YUH-60 and YUH-61 tail rotors. Computing resources were state of the art: "I was using an IBM 360 with card decks. I'd put in about 15 or 20 runs every night. About half them would crash. One room in my house was full of large computer printouts. My wife, Nancy, made me throw them away after I got my doctor of science degree."

Dr. Schrage served as an engineer, manager and senior executive with AVSCOM and the re-cast Army Aviation Research and Development Command (AVRADCOM). "It was kind of a field day for us to develop new technologies," he said. Schrage became the aeromechanics chief for the OH-58D Army Helicopter Improvement Program (AHIP) and oversaw the CH-47D Chinook modernization with composite main rotor blades.

As director for advanced systems, Schrage subsequently led concept formulation for the Light Helicopter Experimental (LHX) program but left for academia before the development contract award. The still-developmental Comanche was canceled 20 years later. "I really felt bad about LHX because it got screwed up," he acknowledged.

"The tiltrotor community at Ames tried to push a tiltrotor. I'm a firm believer in tiltrotor technology, but not for the LHX mission —the size, the weight, the complexity just didn't fit the requirement for the number of aircraft we were seeking." Backlash from Army leadership constrained LHX to a conventional helicopter configuration with unrealistic empty weight. "If we would have let the system do the tradeoffs, we would have come up with something other than a conventional helicopter. I'm not sure what it would have been. It might have been a compound. It might have been a coaxial helicopter."

Schrage concluded, "So much of the time when something goes wrong, the technical community will say 'It's the user who put these unrealistic requirements in place.' The LHX was a prime example of where that wasn't true. The idea was to really do that tradeoff determination process the way it was done for UTTAS and to some extent for the AAH. UTTAS went through the process of tradeoff analysis in six months. Today, everything is 'joint.' Things stretch out."

Aviation to Academia

An unsolicited Georgia Tech proposal to set up an interdisciplinary rotorcraft center of excellence for the Army bore fruit in the early 1980s. Dr. Schrage observed, "A lot of that was based on the immaturity of modeling and simulation during the '70s that needed some long-term research." A 1980 vertical lift panel led by then-Assistant Secretary of the Army Norm Augustine resulted in the initiation of Rotorcraft Centers of Excellence, with the first three centers funded in 1982.

With AVRADCOM converted back to AVSCOM under new readiness-focused leadership, Schrage accepted a professor's position at the Georgia Tech Rotorcraft Center of Excellence. "I could see for the next 10 years I was going to be solving readiness problems for Army aviation as opposed to doing R&D [research and development]. I left AVRADCOM in January 1984 to be the rotorcraft design professor at Georgia Tech. There hasn't been a successful Army Aviation development program since."

Georgia Tech had an established curriculum in vertical flight and had graduated many of the Army Aviation leaders who led the UTTAS and AAH efforts. The opportunity to build an interdisciplinary center was intriguing. "When I got to Georgia Tech in 1984, it was strictly aerodynamics, aeroelasticity, structural dynamics and materials. I'd just come through the AHIP and LHX, and I knew that flight mechanics, controls and autonomy were going to be very, very big. We developed a flight simulation laboratory." Dr. Schrage was named RCOE (now VLRCOE) director in 1986. "We introduced flight mechanics and controls as a discipline in the second proposal we made." The Georgia Tech VLRCOE has been renewed seven times and is today the only VLRCOE that has been funded continuously since 1982.

At Georgia Tech, Schrage has served on the Army Science Board and supported US Air Force, Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA) and other government studies. An autonomous scout rotorcraft testbed initiative in the early 1990s demonstrated Georgia Tech's small Yamaha R-Max autonomous helicopter — designated "GTMax" — and the Sikorsky Cypher UAS at Berry College in Rome, Georgia. "We wanted to focus on how you could integrate these autonomous technologies," explained Schrage. The Defense Advanced Research Projects Agency (DARPA) subsequently teamed universities and industry on its Software-Enabled Control (SEC) program. "It was about integrating this middleware plug-and-play architecture with different control algorithms for autonomous vehicle control. We became the integrator for the final rotary-wing demonstrations." Collaborative researchers used a GTMax to peek in urban windows at Fort Benning, Texas. "I worked on a lot of advanced programs. To me, the SEC program was probably the best and would probably have had the most influence." The effort stalled after a successful first phase. "It was partly due to the Army aviation not-invented-here syndrome."

Dr. Schrage explained, "In recent years I have tried with little success to move Georgia Tech and the other RCOEs toward research in cyber-physical vehicle systems and joint multidisciplinary design analysis and optimization. Traditionally, we design the air vehicle and then try to design the control system to make it stable and do what it does. Cyber-physical air vehicles mean designing the flight controls with autonomous capability. How you design the vehicle is going to be largely determined in today's environment by what kinds of software and controls integration you're going to have."

Dan Schrage joined the American Helicopter Society in 1974 and served as Midwest Regional VP, and later, Southeastern Regional VP on the AHS Board of Directors; chair of the dynamics, systems engineering and supportability technical committees; and Deputy Technical Director for Aeromechanics. He was also the 1999 AHS Alexander A. Nikolsky Honorary Lecturer. "That Nikolsky Lecture I gave about integrated product and process development is something we've implemented at Georgia Tech. Our aerospace design laboratory is the biggest in the world. The rotorcraft community is a very conservative community when it comes to making changes. Yes, these things are very complex, but in many cases, they're the only thing that can do the job."

Dan Schrage continues to teach and advise at Georgia Tech. "I teach a safety-by-design and flight certification course which has been well-received. I'm probably going to teach that next semester, even though I'm going to retire 1 March. Then I hope to come back as Professor Emeritus. I also run another lab called integrated product life-cycle engineering. That's where we do the STEM education and teach summer camps, and we do a lot of product life-cycle things."

The Hummingbuzz demonstrator will fly initially in an all-electric form, but needs battery and motor advances to make fully-electric vertical flight practical. "I think it's coming, but it's not here yet," said Dr. Schrage. "I think you're going to see more hybrid-electric VTOL systems between now and 2025 or so. That's what I'm trying to do in my swan-song here at the Vertical Lift Center."

Note: Dr. Marilyn Smith took over as director of the Georgia Tech VLRCOE on Nov. 19, 2018.