

The Sky is Not the Limit

YEAR IN REVIEW 2015-2016

Georgia Tech **Daniel Guggenheim School
of Aerospace Engineering**

No Limits

September 2016



In my 7+ years at Tech, I've developed a bit of a reputation among my AE colleagues: I'm the guy who does not recognize limits – on ambition, innovation, achievement, and, some would say, *time*.

Who needs time to sleep when Mars is still out there, waiting for a visit from Georgia Tech?

And yet, as we reflect back on the past year, even I am struck by our achievements. If budgets were sometimes lean and time was short, AE students, faculty, staff, and alumni nevertheless pushed forward as though there were no limits. The report you are holding bears witness to their limitless ambitions.

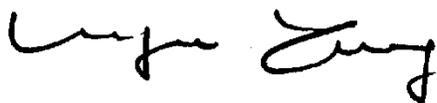
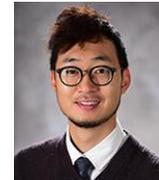
In September of 2015, our undergraduate program was once again rated #2 in the nation by *U.S. News & World Report*. A few months later, our graduate program jumped from #5 to #2, the highest ranking it has ever achieved. Among publicly funded aerospace engineering schools, we are actually #1!

Throughout the year, we addressed shortfalls in our staffing, starting with the recruitment of Dr. **Claudio Di Leo** to our faculty, and Dr. **Oksana Gomas** and **Jinwoo Lee** to our Academic Advising Office. **Tamecia Wright** has fit right in as our new HR coordinator. We even laid the groundwork for the new Aero Maker Space (more on that next year).

The success of the AE School was also its downfall in FY 16, as two pillars were recruited by other institutions. We tip our hat to the University of Colorado, which scooped up Dr. **Robert Braun** to serve as the new engineering dean on its Boulder campus, and to Purdue University, where Dr. **Dave Spencer** is now teaching.

For all of the emphasis we place on research, publications are the portal to wider audiences and impact. In FY 16, a survey of graduating AE students found that 10 percent of our undergraduates, 30 percent of our MS students, and 80 percent of our doctoral students had published during their tenure at Tech. We look forward to strengthening this trend in FY '17.

We also look forward to seeing more of our supporters on campus in FY 17. **That means you**. Come to campus to attend a lecture, talk with a faculty, recruit our students, or tour our facilities. And, if you cannot make it to North Avenue, I invite you to visit us *virtually*: the AE website (ae.gatech.edu) also received a much-deserved redesign in FY 16.



Vigor Yang

William R. T. Oakes Professor and School Chair
Daniel Guggenheim School of Aerospace Engineering

FACULTY HIGHLIGHTS

AE faculty achievements - in teaching, research, scholarship, and service - continued to impact the aerospace engineering community in FY 16. Nowhere was this more evident than in the area of publications, where more than 150 faculty-authored articles appeared in AIAA publications, and several dozen were featured in AHS and ASME publications.

Prof. **Robert Braun**'s 2007 article, "Mars Entry, Descent and Landing Challenges" was recognized as the most-cited article between 2005 and 2010 by the Journal of Spacecraft & Rockets ... Prof. **Vigor Yang**'s 2009 article on swirl-stabilized combustion was identified as one of the top three most downloaded papers in combustion from ScienceDirect

between 2005 and 2015, with 13,955 downloads as of August 1, 2015 ... Prof. **J.V. R. Prasad** received the AeroLion Technologies Outstanding Journal Paper Award from the *International Journal of Unmanned Systems* for his co-authorship of "Development and Flight Test Evaluations of an Autonomous Obstacle Avoidance System for a Rotary-Wing UAV" ... "Aerodynamics of Finite Bluff Bodies," an article that Prof. **Marilyn Smith** co-authored with one of her top graduate students, **Daniel Prosser**, was published in the *Journal of Fluid Mechanics*. The two also collaborated on "A Physics-based Reduced Order Aerodynamics Model for Bluff Bodies Unsteady, Arbitrary Motion," which was published in the *Journal of the American Helicopter Society* ... Prof. **Timothy Lieuwen** had a singularly successful - and busy - year. His exhaustive review of transverse instabilities in power generation and propulsion devices appeared in *Progress in Energy and Combustion Sciences* (PECS). He was also selected to hold the David Lewis Chair in Aerospace Engineering, an honor previously held by NAE member **Ben T. Zinn**. Lieuwen was elected to the Board of Governors for the Oakridge National Lab. and served as the program chair for the 2016 International Gas Turbine Turbo Expo — the largest gas turbine technical forum in the world... licensed patents to Exxon Mobil for detecting the tell-tale signs of an impending blowout — a significant challenge for modern low-emissions energy devices ... Prof. **Dewey Hodges** collaborated with Carlos Roi thmayr in publishing an engineering textbook, *Dynamics: Theory and Application of Kane's Method* ... Profs. **Marilyn Smith** and **Graeme Kennedy** were awarded a 3-year, \$572,979 contract with NASA Langley to



Prof. Robert Braun



Prof. Timothy Lieuwen



Prof. Marilyn Smith



Prof. Graeme Kennedy

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pursue their work, "An Efficient Scalable Framework for Aeroelastic Analysis and Adjoint-based Sensitivities Using FUN3D and TACS" ... Collaborating with the University of Maryland, **Smith** also received a \$570,632 grant for a 3-year project, "Identification and Quantification of the Role of Turbulence in Aircraft/Ship Aerodynamics" from the Office of Naval Research ... Prof. **Panagiotis Tsiotras** won a 3-year \$800,000 National Science Foundation grant to work with Prof. **Karen Feigh** on "Adaptive Intelligence for Cyber-Physical Automotive Active Safety — System Design and Evaluation" ... Prof. **Jerry Seitzman** received a 3-year, \$800,000 grant to work with AE Profs. **Timothy Lieuwen**, **Suresh Menon**, and **Brian German** on "High Temperature, Low NOx Combustion Concept Development" ... Profs. **Mitchell Walker** and **Julian Rimoli** will serve as co-PIs on a 3-year, \$1,050,000 Air Force Office of Scientific Research project, "High-Fidelity Coupling of Predictive Plasma-Wall Models" ... **Walker** will also serve as co-PI on a one-year, \$473,391 DARPA grant, "Magnetohydrodynamic Power Generation for Upper-Stage Rockets" ... Prof. **Joseph H. Saleh** was chosen by the Institute to receive the Class of 1940 W. Roane Beard Outstanding Teacher Award ... Prof. **Stephen Ruffin** was selected by the Institute to receive a 2015 Diversity Champion Award for his work promoting STEM through the Space Grant Consortium... Prof. **Vigor Yang** was elected to Academician of Academia Sinica, the highest honor bestowed on scholars of Chinese origin ... Yang was also chosen by AIAA to give the 2016 von Kármán lecture in astronautics... Prof. **Dewey Hodges** gave a keynote lecture, entitled "Unified Approach for Accurate and Efficient Modeling of Beams and Plates Made of Thick Composite Laminates" at the 2016 AHS International... Profs. **Marilyn Smith**, and **John-Paul Clarke** were each elected Fellow of the AIAA ... Clarke was also recognized by the Society of Automotive Engineers



Prof. Karen Feigh



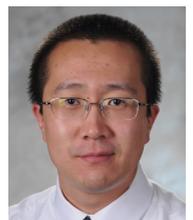
Prof. Mitchell Walker



Prof. Julian Rimoli



Prof. J. P. Clarke



Prof. Wenting Sun



(SAE) with the 2016 Environmental Excellence in

STUDENT HIGHLIGHTS

In competitions, scholarship, and innovation AE undergraduate and graduate students continued an ambitious legacy that has come to define the Daniel Guggenheim School:

Graduate student **Tom Neuman** won top honors in NASA's 2014-15 University Design Challenge: All-electric Aviation Vehicle Competition for his solo work on The Vapor, an airplane prototype that is competitive with the Cirrus SR-33. The plane had to capable of taking off in less than 3,000 feet, flying at least 575 miles, and cruising at 150 miles-per-hour while carrying 400 pounds... Three AE-based teams took home top honors and about \$3,750 at the 32nd Annual American Helicopter Student Design Competition. **AirBuzz**, a quad tilt-rotor UAV, and **HARETC**, an electric tandem, took home first and third place in the undergrad division while **GTStork** took second place overall in the graduate division...



Henderson Johnson



Connie Liu



Shane Lympany



Julian Brew

Henderson Johnson, the reigning Mr. Georgia Tech, was chosen to receive a National Science Foundation scholarship, which will fund his graduate work with Prof. **Tim Lieuwen** on the burn characteristics of alternative liquid fuels. He also earned the Alivin M. Ferst Fellow grad students **Connie Liu** and **Shane Lympany** also received NSF's to explore, respectively, the conversion of acoustic energy into vortical energy, and the effect temperature has on Hall Thruster efficiency... **Imon Chakraborty** was selected by Aviation Week magazine and AIAA for inclusion in the 2015 "Tomorrow's Engineering Leaders: 20 Twenties' List," an annual prediction of emerging talent... Fellow grad student **Evan Harrison** was named the 2016 Department of Transportation Student of the Year for FAA Centers of Excellence in recognition of his research, Safety Analysis for General Aviation, which aims at enhancing the safety of general aviation operations through the improved use of flight data... Graduate students **Julian Brew** and **Michael Werner** were selected to receive a prestigious NASA Space Technology Research Fellowship – support



Ruling the Skies ...Again

For the second year in a row, two AE-based design teams took home top honors for their vehicles, **Chicken of the Sky** and **Buzzed Bomber**, in the Society of Automotive Engineers' Aero Design East competition. In the Micro class ASDL's "Chicken of the Sky" aircraft took first place overall and was recognized for hauling the second highest payload fraction. In the Advanced class the team's "Buzzed Bomber" took first place overall, first place in its design report, and had the best payload drop at the competition.

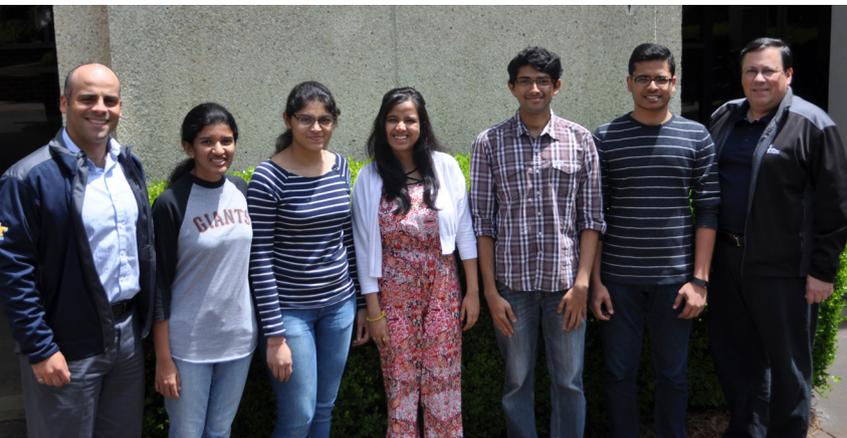
hat guarantees their research funding through the end of their doctoral studies...

For the third year in a row, Sigma Gamma Tau, the honor society for aerospace engineering, chose an AE undergraduate for the Undergraduate of the Year for the Southeast Region: Honors Student **Swapnil Pujari**...

Of the 24 scholarships awarded the Vertical Flight Foundation of the American Helicopter Society, six (\$18,000) went to AE students who are rising stars in the rotorcraft community: **Avani Gupta**, **Jackson Merkl**, **Amanda Grubb**, **Mohit Gupta**, **Kevin Jacobson**, and **Lee Whitcher**.



by



Making the Skies a Little Greener

An ASDL-based team of grad students prevailed in the 2016 Airbus Innovation Showdown, winning the \$5,000 grand prize and besting a field of more than 300 competitors by designing a system that extracts usable energy from onboard organic waste on airplanes. The energy is intended to power subsystems on the aircraft. Getting to the #1 spot involved more than good engineering, as students survived several rounds of critiques by Airbus judges and a formal business presentation, made via the Internet.

COMMITTING OURSELVES TODAY FOR TOMORROW



As an alumnus of the Daniel Guggenheim School of Aerospace Engineering, I take great pride in the innovation that is the hallmark of this institution. It has created great opportunities for me, in my career. As the chair of the School's Advisory Council, I am committed to building upon that legacy for the next generation of aerospace engineers.

The rigor of our program today will be the foundation of tomorrow's leaders.

My colleagues on the Advisory Council share that commitment and something more: we are all constantly scanning our horizons — in business, government, academia, and beyond — to find the next big challenge — real-world engineering problems worthy of the talent that AE students bring to their endeavors.

I invite you to support our quest,

John E. Laughter, BSAE '93
Chair, Aerospace Engineering School Advisory Council

2015-2016 AESAC Members



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Engineering &
Technical Operations
Lockheed Martin
Aeronautics



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The Boeing Company



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and Engineering
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Aerospace



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Product Development,
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Co-managing Officer,
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Integrated Defense
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Company



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AE '85
AESAC Chair Emeritus
Former Undersecretary
of Defense, Acquisition,
Logistics, Technology



Stephen M. Younger
Vice President and Chief
Technologist
Northrop Grumman
Technical Services

RESEARCH HIGHLIGHTS

Smith: Introducing the Army to GTABB

Prof. **Marilyn Smith**'s research team made major strides in reduced-order modeling and simulation techniques, prompting the US Army to adopt the Georgia Tech Aerodynamics for Bluff Bodies (GTABB) model, a physics-based reduced-order modeling for bodies undergoing dynamic motion. The model provides an accurate estimation of forward flight instabilities in loads that are tethered to rotorcraft vehicles. The results will allow researchers to develop real-time simulator training for tethered and free-falling bodies for humanitarian and military applications.

"In the past, our efforts to effectively assist people trapped in mountainous regions or other remote areas during natural disasters has been severely limited by the problems we face transporting needed equipment and supplies. Those loads, tethered to the rotorcraft, create instability that slows down the entire transport," said Smith.

"Our work at Tech could deliver real solutions to this problem, which is also faced by our armed forces."

The model has also been used to identify methods for stabilizing tumbling unmanned quadrotors — UAVs that must be staged from a moving aircraft in order to reach remote destinations with their payloads. Since demonstrating the model's robustness using flight test bed, Smith's team has been identifying new configurations for its use and investigating its sensitivity to different influences, such as atmospheric turbulence.

Collaborating with Suresh Menon, Smith has also helped realize greater accuracy and reduced costs in computational fluid mechanics as they apply to the hybrid turbulence modeling approach for transitional flows. Their work permits the identification of physics in rotating hubs and transient dynamic behavior. This has implications for a broad range of engineering disciplines and applications — from rotorcraft design to biomedical engineering.



Marilyn Smith

Tsiotras: Mimicking Human Behavior

Under the auspices of the Multidisciplinary University Research Initiative (MURI), AE professor **Panagiotis Tsiotras** and researchers from MIT and the University of Southern California are challenging state-of-the-art computer technology to investigate perception and planning algorithms that mimic human behavior. Their 5-year, \$6.25 million project could eventually help engineers address some tough questions, like: what allows humans to operate efficiently in complex, dynamically changing, and uncertain environments? How do professional athletes and race car drivers make highly complex decisions with just milliseconds to think?

More immediately, this work will help engineers tackle the control of autonomous vehicles in abnormal regimes — something Tsiotras has been working on with his colleague Evangelos Theodorou and faculty from the School of Interactive Computing (IC). Funded by the Army Research Office, that team has been devising novel ways for the self-driving cars

of tomorrow to navigate safely under actual road conditions. Their technique — which uses advanced algorithms, onboard computing, and specially installed sensing devices — is garnering some serious attention, too.

But the algorithms Tsiotras's team has been developing have a broader applicability, as they can be used in any system that needs to reach optimal decisions and execute optimal actions under severe time constraints in an unstructured and uncertain environment.

"All future intelligent autonomous robotic systems will benefit from the results of these research efforts," said Tsiotras. "In order to be able to work with human-like intelligence and robustness in a variety of unpredictable situations, such algorithms will be an indispensable ingredient running inside the brains of these machines."



Panagiotis Tsiotras

German: Electrifying Air Travel

The growing demand for electric and hybrid-electric aircraft propulsion technologies is behind the Economical Thin Haul Aviation Concepts (ETHACS) project, a \$800K NASA-funded initiative led by Prof. **Brian German**. German's team is exploring ways to assess the feasibility of electric aircraft for the so-called 'thin haul' aviation market.

"The thin haul market is a large distribution of short air routes, each with limited and sporadic demand, but, collectively, with potential for enormous aggregate air traffic volume," said German, who is collaborating with researchers from GT-CEE, Ohio State and Penn State as well as AE colleagues **Simon Briceno, John-Paul Clarke, Graeme Kennedy, Dimitri Mavris, and Amy Pritchett**.

"This market is largely infeasible right now because fuel-burning aircraft present higher operation costs and lower fuel efficiency. But the thin haul market could expand greatly by replacing car trips if operating costs and corresponding ticket prices can be adequately reduced."

The multidisciplinary project brings together many components, from aircraft technologies and design to new ways for commuter aircraft to interact with air traffic control. For instance, it will benchmark existing operations by modeling

the route networks and estimating the operating economics of several representative commuter airlines. With this information, the researchers can assess the economic feasibility of thin haul electric aircraft as critical technology metrics--e.g. battery-specific energy and charging rate--mature.



Brian German

German's team is developing algorithms to energy-size electric aircraft for particular route schedules, factoring in the need for battery recharging and the potential benefits of battery swapping between routes. The team is also assessing the impact of grid electricity cost fluctuations and developing maintenance cost models for electric propulsion system components based on their reliability.

The project will allow the team to explore additional innovations including:

- technologies that improve aerodynamic efficiency, ride quality, and noise;
- models that estimate thin haul ticket demand;
- new approach and departure trajectories that allow small aircraft to merge into air traffic patterns at large airports.

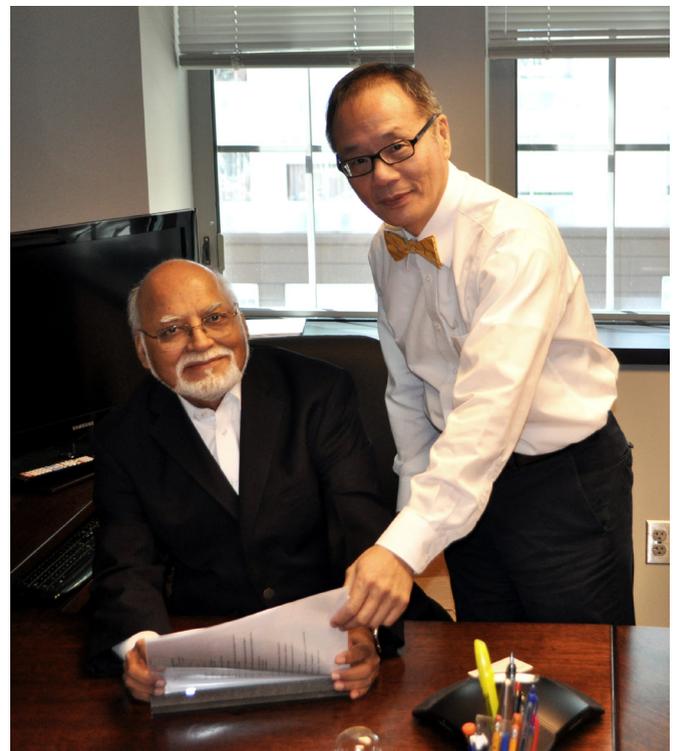
Ahuja & Yang: Developing Better Rockets

Regents Professor **Dr. Krishan Ahuja** teamed up with the Georgia Tech Research Institute (GTRI) to spearhead a two-year, \$7,857,568 collaboration to develop a high-performance, stable combustion technology for rocket engines. Funded through the Air Force Space & Missile Systems Center, the Combustion Stability Tool Development (CSTD) has allowed Ahuja to work with three of his longtime AE colleagues — William R. T. Oakes Professor **Vigor Yang**, Lewis Professor **Tim Lieuwen**, and Regents Professor **Lakshmi Sankar** — on the development of design tools that will eventually enable the United States to better predict combustion instability in its spacecraft.

"Current rocket engines are largely based on 30-50 years old designs, which were largely supported by costly trial and error testing. This program provides us a unique opportunity to develop a software tool to optimize new rocket engine designs while reducing the requirement for costly testing. This will be accomplished by making the most of the recent advancements in computing, modeling, computational fluid dynamics, acoustics, and visualization to the simulation-based design of a new generation of high performance rocket engines," said Ahuja.

With the help of Purdue University Professor **Bill Anderson**, the group has been focusing on developing of a suite of software-based design tools for predicting and analyzing stability characteristics of combustion devices based on hydrocarbon-fueled, oxidizer-rich staged combustion rocket engine cycles. Their research is expected to be completed in 2017, with a demonstration of the new technology to be executed in 2019.

The effort is supporting more than 10 graduate students and a number of undergraduate students and research engineers both in the AE School and at GTRI. The project is also supporting faculty and students in the School of Industrial Engineering.



Krishan Ahuja and Vigor Yang

Launching the Next Generation of Aerospace Engineers...and Entrepreneurs

It's a great time to be a space geek at GT-AE.

No one knows that better than E. Glenn Lightsey, Brian Gunter, and Marcus Holzinger — three professors who are reshaping the School's grasp on space exploration.

"The field of space exploration is undergoing a market revolution," says Lightsey, who designed and launched 6 satellites with students at the University of Texas before joining the AE faculty in 2015. "The cost of launch and the cost of the satellites themselves are dropping by an order of magnitude each. That means increased access to space — not just for governments, but also for space entrepreneurs who are speeding the pace of innovation and improving our quality of life on earth. Our job is to help them get there."

In the spring of 2016, Lightsey oversaw the installation of a \$350K S-Band satellite ground station that will improve his team's ability to track and communicate with the growing number of spacecraft in orbit. Housed inside a 17-foot white globe on top of the GTRI complex in Cobb County, this high-gain antenna can detect signals from all manner of space-borne vehicles — including the upcoming launches of Gunter's and Holzinger's satellites. And instead of decoding incoming data using traditional radios, the station is equipped with modern and versatile software-defined radios.

"The software means we can easily change parameters to communicate with different satellites. We can support a wide range of missions with just one set of hardware."

Lightsey is encouraged by the School's recent investments in sophisticated hardware — including a thermal-vacuum chamber, a GPS signal simulator, and a magnetic field cage, for instance. Next genera-

tion equipment will help GT researchers design and test new satellites with a sophistication that was previously available only to large aerospace companies and government labs. And it will also help them to educate the next generation of engineers on all aspects of the space mission lifecycle — from design through operations.

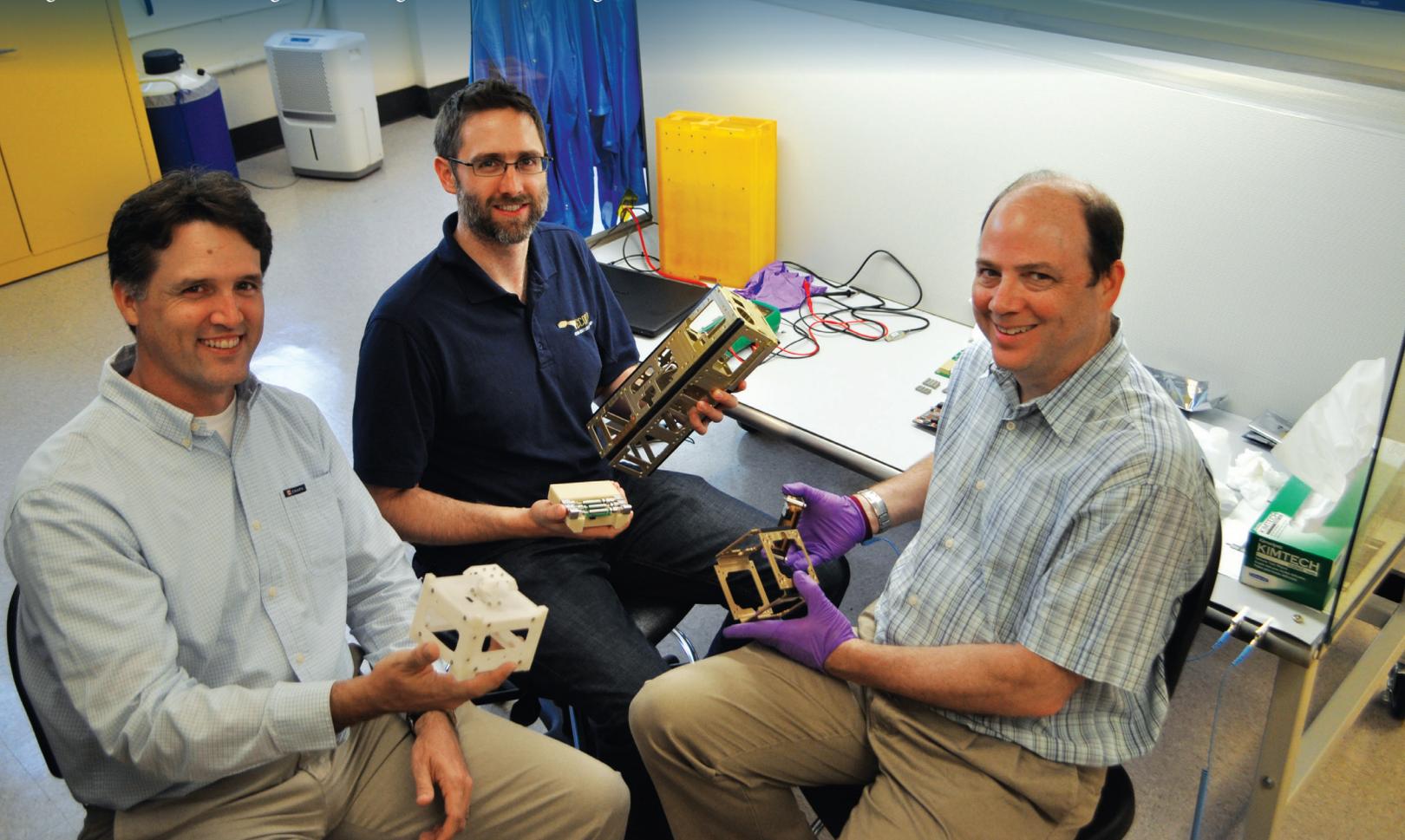
Gunter and Holzinger's upcoming satellite missions are already providing that final test. Scheduled to launch in 2017, Gunter's RANGE mission consists of two cubesats, each measuring 10x10x15 cm, that will fly in a leader-follower formation. The relative positions of the satellites will be measured using a compact inter-satellite laser ranging system that will double as a laser communications system. The mission seeks to validate technology that could eventually track orbits down to mere centimeters, and measure the relative distance between the satellites down to millimeters, Gunter said.

Holzinger's RECONSO mission is equally ambitious. Scheduled to launch in 2018, RECONSO will put a low-cost optical payload in Low Earth Orbit where it will be able to detect and track new and existing space objects — data that will contribute to the expansion and maintenance of the Space Object Catalog. RECONSO will demonstrate space tracking functions in space that have previously been conducted by ground equipment. RECONSO was selected for flight by the US Air Force from a national competition of university satellite projects.

Working together, Lightsey, Gunter, and Holzinger are pursuing projects that will continue to engage students in the design and construction of new satellites.

"There is no shortage of opportunities to explore space," says Lightsey. "And we have the equipment, people, and will to do it."

"Decreased costs mean increased access to space — not just for governments, but also for space entrepreneurs... Our job is to help them get there."



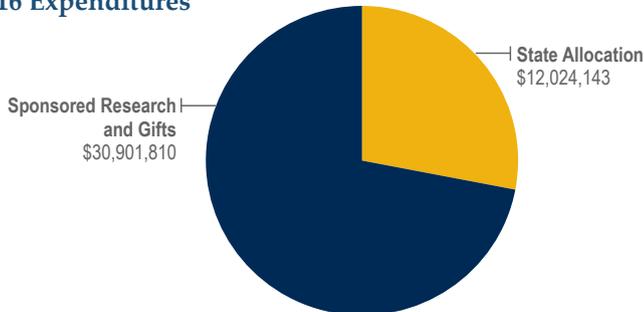
In FY16, the School had expenditures of \$42,925,953 which were funded by a combination of the School's state allocation from the Institute, sponsored research contracts, and gifts. A large percentage of the total expenditures went to support salaries of faculty, staff, research faculty, and graduate researchers.

Most of AE's other expenses were for materials, supplies, travel, and equipment in support of the School's research and teaching mission.

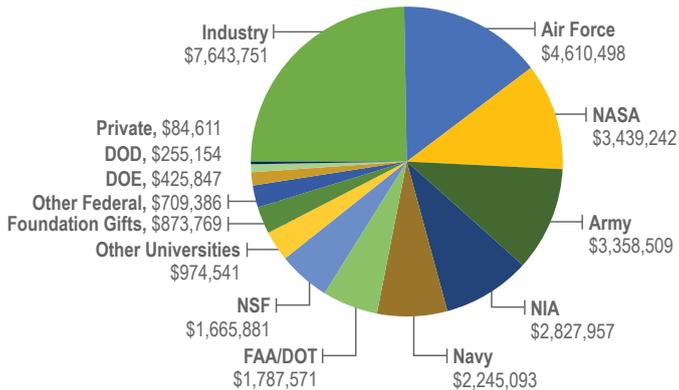
Research funding from outside sources in FY16 totaled \$30,901,810: \$21,590,294 from the U.S. military and federal agencies; \$7,643,750 from industry; \$873,769 from gifts; and \$793,997 from other sources (e.g. local, state, and other governments).

AE's state allocations were \$12,024,143 for our teaching mission, general operations, and funding in support of new faculty renovation, furniture, and equipment needs.

FY16 Expenditures



FY16 Research Funding



The financial support of our many friends and alumni is the bedrock upon which the Daniel Guggenheim School of Aerospace Engineering has become one of the leading schools in the world. With your support, that legacy continues.



Farah A. Kashlan

Farah A. Kashlan
Development Director
Daniel Guggenheim School of Aerospace Engineering
farah.kashlan@ae.gatech.edu

Thank You!

A warm thanks to the following individuals and corporations who have contributed to the AE legacy over the past year.

Accenture • AIAA Foundation • Airbus Group • Mr. W. Lee Akridge • Alta Solutions, Inc. • ARCS Foundation, Inc. • Mr. Larry M. Balkin • Mr. & Mrs. Michael R. Buchanan • LTC Charles L. Budde • Mrs. Mary W. Burnett • Dr. & Mrs. Michael Chang • Dr. & Mrs. James I. Craig • Mr. & Mrs. Marcus J. Dash • Dr. Frederick D. Eichenbaum • Epps Aviation • Mr. Patrick Epps • Dr. & Mrs. Eric M. Feron • Funai Foundation for Information Technology • Mr. & Mrs. Eric Gebhardt • Dr. & Mrs. Robin B. Gray • Mr. C. Andrew Hardin • Human Factors & Ergonomics Society • Dr. Jeff I. Jagoda • Krone Foundation, Inc. • Mr. Roger A. & Mrs. Helen Krone • L-3 Communications Electron Tech, Inc. • Mr. and Mrs. John E. Laughter • Dr. Tim C. Lieuwen • Linde Gas North America, LLC • Lockheed Martin • Lockheed Martin Space Systems • Mr. & Mrs. Alvaro J. Lopez • Mr. Joseph P. Lopez • Middle Georgia State University • National Institute of Aerospace • Mr. & Mrs. Christopher Nicholson • Northrop Grumman • Planetary Society • Pratt & Whitney • Mr. Darrell W. Preble • Rolls-Royce North America Tech, Inc. • Saab AB • Dr. Jerry M. Seitzman • Sikorsky Aircraft Corporation • Dr. Marilyn Smith & Mr. Robert Smith, Jr. • Society of Automotive Engineers, Inc. • United Technologies Corporation • Mr. Alan L. Weinberger • Dr. & Mrs. Ben T. Zinn • Mr. & Mrs. Gary Weissel • Mr. Aleck C. Bond • Mr. Hugh F. Hunter

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FY16 AT A GLANCE



No.2

2014 ranking for undergraduate program, *U.S. News & World Report*

No.2

2015 ranking for graduate program, *U.S. News & World Report*

Graduate & undergraduate enrollment, Fall I2015

For more than a decade GT-AE's undergraduate and graduate programs have been ranked in the top 5, nationally.

students received degrees from the Daniel Guggenheim School of Aerospace Engineering

35% of eligible GT-AE undergrads were involved in research

31% of eligible GT-AE undergrads were involved in internships/co-ops