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Graduate School of Engineering and Management, Air Force Institute of Technology

AIR FORCE INSTITUTE OF TECHNOLOGY GRADUATE SCHOOL OF ENGINEERING & MANAGEMENT

AFIT ENGINEER

The Graduate School of the U.S. Air Force

September 2022 | Vol. 4, Issue 3

DAF Innovation Destination

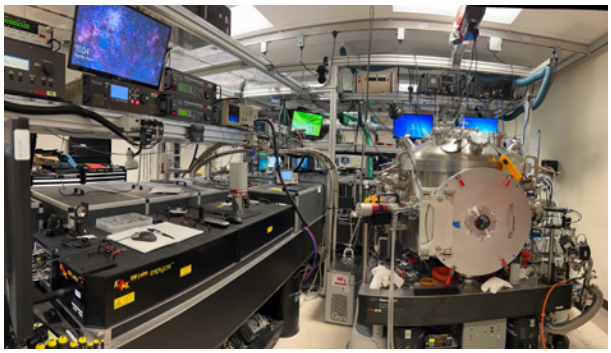
Researchers Achieve Microscale, Cost-effective Laser-induced Nuclear Fusion

By Dr. Anil Patnaik, Dr. Michael Dexter, Dr. Juan Manfredi, Kyle Frische, Benjamin Knight and Connor Gautam
Air Force Institute of Technology

The Air Force Institute of Technology's Extreme Light Laboratory, led by Dr. Anil Patnaik and Dr. Michael Dexter, achieved microscale laser-induced nuclear fusion for the first time ever at Wright-Patterson AFB. This historic effort was the result of a strong collaboration between AFIT and the Air Force Research Laboratory/Aerospace Systems Directorate/Turbine Engine Division (AFRL/RQT). The research team successfully demonstrated the ability to produce microscale nuclear fusion reactions in a liquid target made up of deuterated water, often known as heavy water, using a tabletop femtosecond laser system. This system is currently generating over 100,000 fusion reactions with each laser pulse and is capable of producing 1000 pulses per second for a total output of 10 million fusion reactions per second.

"This finding underscores the need for investigating a trove of underlying fundamental physics of high-energy density relativistic laser-plasma interactions. In fact, these results are just the beginning. With a modest investment, it is possible to increase the output of this system by several orders of magnitude that will open up a host of possible defense relevant applications," explained Patnaik.

The system takes advantage of a property called target normal sheath acceleration in which the laser pulse acts as a very small particle accelerator, accelerating protons, or in the case of heavy water deuterons, to energies necessary to fuse. This process requires a laser that can produce extremely strong electric fields ($\sim 10^{18} - 10^{19}$ W/cm^2) at the focus of the laser beam over a very short distance (100 – 200 nm). In this case, the laser produces a pulse that exists for only 30 femtoseconds (that is 30 times a millionth of a billionth of a second) and contains only about as much energy as a flash from a small led light. However, the extremely short duration of this laser pulse results in extremely large energy density, which produces the massive electric fields necessary for this effect.



U.S. Air Force contributed photo

The Extreme Light Laboratory that houses one of the powerful ultrashort lasers that enabled researchers to realize the table-top accelerator capability and neutron generation.

Another unique aspect to this work is the fact that it uses a liquid target that allows the system to run for extended times without the need to replace the target. Most of the work done in this field uses solid targets that are often expensive to produce; such targets are only useful for a limited number of shots since each laser pulse damages the target. As a result, this system can operate at a fraction of the cost of a comparable system using solid targets.

The work has been supported by the "ultrafast laser-matter interactions" portfolio managed by Dr. Andrew Strickrath at AFOSR since 2012 and is fostered by a multi-university collaboration including The Ohio State University, Miami University, Marietta College, and California State University (Channel Island).

"This research represents a steppingstone in the development of a low-cost, portable, combined-radiation environment necessary for the verification and validation of critical components in spacecraft such as those required for deep-space exploration. Additionally, this system could eventually be scaled down to provide on demand sources of radiation to conduct testing and verification of aircraft components on the flight line," said Dexter.

The Extreme Light Laboratory is primarily funded by AFOSR and smaller funds from other agencies such as NSF, DOE, and DTRA. AFIT currently has a funding proposal under review with AFOSR to continue research in the lab for next three years.

INSIDE THIS ISSUE

Find past issues online at:
www.afit.edu/EN/afitengineer

Graduate School Welcomes New Students and Celebrates Fall Graduates


Dr. Adedeji Badiru

Readers, supporters, and observers, welcome to another issue of the *AFIT Engineer* Newsletter, which is now in its fourth year at Volume 4, Issue 3. Innovation is the theme for this September 2022 issue. You will see several articles and topics related to innovation throughout the contents.

To kick things off, I am delighted to welcome 336 new students to the Graduate School of Engineering and Management also brag about our innovative responses to COVID-19 by conducting graduation ceremonies in adaptive modes, based on the prevailing status of the pandemic. Our latest graduation ceremony occurred on 15 September in a COVID-dictated modified formation. We graduated 63 APT (Awaiting Pilot Training) students, 17 MS students, and 24 Ph.D. students. We were fortunate to have Dr. Vince Russo (retired USAF SES) as the graduation speaker. The practical lessons learned and projected by his talk are still reverberating through the AFIT community. We all extend a great "AFIT Thank-You Cheer" to Dr. Russo.

Please enjoy this newsletter issue and return next quarter for the December issue of the ***AFIT Engineer.***

With innovation, we thrive.

Adedeji B. Badiru, Ph.D., PE
Dean, Graduate School of Engineering and Management

Call for Submissions to the SERC Doctoral Student Forum

By Adedeji Badiru, Ph.D.
Dean, Graduate School of Engineering and Management
Air Force Institute of Technology

People make systems. People are the key components of any system. Technically-prepared people form the foundation for the success of Department of Defense programs. AFIT recently hosted a Digital Literacy Symposium at the neighboring Central State University. This demonstration of support for diversity programs fits the DoD program described below on account of its systems innovation content.

The United States Department of Defense is showing its commitment to cultivating STEM talent with plans to create a new University Affiliated Research Center (UARC) at an HBCU. This center would be the 15th UARC and the first associated with the Department of the U.S. Air Force. The DoD SERC (Systems Engineering Research Center) is seeking a diverse pool of future leaders in systems engineering to highlight their research at the annual research review to an audience of academia, government, and industry. The SERC Doctoral Student Forum on Nov. 17, 2022 is an ideal showcase for talented systems engineering students and interdisciplinary collaborators. This opportunity is not limited to systems engineering students.

In my view, everything we do at AFIT has a "systems twist" to it. Students conducting innovative systems engineering (SE) related research and exemplifying a passion for addressing the most challenging systems issues facing the Department of Defense and other federal departments and agencies are encouraged to submit. AFIT is among the SERC institutions eligible to submit.

VISIT THE LINK ONLINE FOR MORE DETAILS
https://lnkd.in/eF7VNKJi

TEACHING WHAT WE RESEARCH. RESEARCHING WHAT WE TEACH.

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AFIT ENGINEER
AFIT Graduate School of Engineering and Management

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STAY CONNECTED www.afit.edu/EN | www.afit.edu/EN/afitengineer

FALL 2022 GRADUATE STUDENTS BY THE NUMBERS

336 New Graduate Students

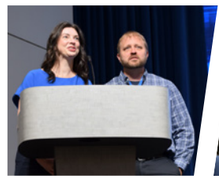
PROGRAMS OF STUDY
- **234** Master's Degree
- Doctoral Degree **19**
- **83** Certificate

8 STUDENT CATEGORIES
+ Air Force
+ Space Force
+ Army
+ Marines
+ Navy
+ National Guard Active Duty
+ DoD Civilians
+ DoD Contractors

6 COUNTRIES REPRESENTED
United States | Australia
Bahrain | Brazil
Israel | Saudi Arabia

The Graduate School of Engineering and Management proudly welcomed 336 students to AFIT during the annual New Student Orientation held on August 31.


U.S. Air Force photos by Katie Scott



New Student Orientation included presentations from AFIT leadership, Graduate School academic departments and the Center for Innovation in Education. All new students received welcome gift bags from the AFIT Foundation.

Graduate School Welcomes 18 New Faculty Members

The third week of September kicks off the Air Force Institute of Technology's New Faculty Orientation for the Graduate School of Engineering and Management. Prior to the start of each new academic year, the Graduate School conducts the orientation to assist new faculty in acclimating to their roles of teaching, advising, and mentoring AFIT's students.

Dr. Alice Grimes, Director of Faculty Development and the Center for Innovation in Education, along with Graduate School leadership and faculty, welcomed 18 new faculty members to AFIT during a four-day virtual orientation. The new faculty group consisted of a mix of both military and civilian faculty members who will join approximately 208 current Graduate School faculty members across six academic departments.

The orientation consisted of a comprehensive review of critical information such as the Education Technology Program support and services, the computer help desk, library services, student records, AFIT research programs, faculty council, lab safety, and more. Upon completion of their orientation, new faculty participated in a Course Development Workshop led by Dr. Brett Borghetti designed to assist them in creating the courses they will instruct.

AFIT Graduate School fall quarter classes begin on Oct. 5.

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THE AIR FORCE INSTITUTE OF TECHNOLOGY

Follow AFIT on LinkedIn and Facebook to meet the new Graduate School faculty and to find all the latest AFIT news.

PATENT AWARDS

Monolithically Integrated Microscale Pressure Sensor on an Optical Fiber Tip

PATENT # 11,326,970 **DATE:** May 10, 2022

INVENTORS: Dr. Hengky Chandrahalim, Assistant Professor of Electrical Engineering, and **Capt. Jeremiah C. Williams** (MS Electrical Engineering, 2020)

ABSTRACT: A passive microscopic Fabry-Pérot Interferometer (FPI) pressure sensor includes an optical fiber and a three-dimensional microscopic optical enclosure. The three-dimensional microscopic optical enclosure includes tubular side walls having lateral pleated corrugations and attached to a cleaved tip of the optical fiber to receive a light signal. An optically reflecting end wall is distally engaged to the tubular side walls to enclose a trapped quantity of gas that longitudinally positions the optically reflecting end wall in relation to ambient air pressure, changing a distance traveled by a light signal reflected back through the optical fiber.

ONLINE LINK:
https://patentimages.storage.googleapis.com/c9/1a/28/9d75b157939e5e/US11326970.pdf

Disk Engine with Circumferential Swirl Radial Combustor

PATENT # 11,415,046 **DATE:** August 16, 2022

INVENTORS: Lt. Col. Brian Bohan, Ph.D., USAF, AFIT Assistant Professor of Aerospace Engineering (PhD Aeronautical Engineering, 2018 & MS Aeronautical Engineering, 2011), **Dr. Marc Polanka**, AFIT Professor of Aerospace Engineering, and **Capt. Bennett Staton,** (M.S. Aeronautical Engineering, 2020, DG)

ABSTRACT: A disk engine and system configured to provide high power at a reduced axial length is disclosed herein. The disk engine includes a radial compressor, a compressor discharge manifold positioned circumferentially about compressor, a combustion chamber positioned within the discharge manifold and a radial turbine positioned radially inward of the combustion chamber.

ONLINE LINK:
https://e.afit.edu/gP2VVb

Noncontact Liquid Crystalline Broadband Optoacoustic Sensors

PATENT # 11,366,054 **DATE:** June 21, 2022

INVENTORS: Dr. Hengky Chandrahalim, Assistant Professor of Electrical Engineering, and **Capt. Michael Dela Cruz,** (MS Electrical Engineering, 2019)

ABSTRACT: An optoacoustic sensor includes a liquid crystal (LC) cell formed between top and bottom plates of transparent material. A transverse grating formed across the LC cell that forms an optical transmission bandgap. A CL is aligned to form a spring-like, tunable Bragg grating that is naturally responsive to external agitations providing a spectral transition regime, or edge, in the optical transmission bandgap of the transverse grating that respond to broadband acoustic waves. The optoacoustic sensor includes a narrowband light source that is oriented to transmit light through the top plate, the LC cell, and the bottom plate. The optoacoustic sensor includes an optoacoustic spectrometer that is oriented below the bottom plate to receive the transmitted light and to record a time-domain modulation of transmission intensity at a selected one of a falling and rising edge of the transmission bandgap for detecting analog acoustic vibration.

ONLINE LINK:
https://patentimages.storage.googleapis.com/05/a4/3f/9e784c82e8c516/US11366054.pdf

GSEM Faculty Research Receives Publication

Dr. Hengky Chandrahalim, AFIT Assistant Professor of Electrical Engineering, and **Capt. Jeremiah C. Williams** (MS Electrical Engineering, 2020) recently received publication of their work titled "Two-Photon Nanomachining of a Micromechanically Enhanced Optical Cavity Sensor on an Optical Fiber Tip" in *Advanced Photonics Research* journal. *Advanced Photonics Research* is a new flagship journal of Wiley-VCH publisher. The work is also featured on the inside front cover of the issue (Vol. 3, Issue 7).

READ THE JOURNAL ARTICLE ONLINE
https://onlinelibrary.wiley.com/doi/10.1002/adpr.202100359

Graduate School Associate Dean of Students Named

Lt. Col. Chris Rondeau

Lt. Col. Chris Rondeau has been named Associate Dean of Students, Graduate School of Engineering and Management at the Air Force Institute of Technology. He leads more than 1,000 joint, international, and civilian students enrolled in graduate engineering and management programs at the school. Rondeau is responsible for all graduate student matters and supervising personnel in support of student services, registrar, and admissions functions.

Rondeau began his career at Robins AFB, GA as a sustainment electronics engineer on common support equipment. He later transferred to Holloman AFB, NM serving as an inertial system test manager working programs that included a variety airframe navigation systems and the gyros on the Hubble Space Telescope. Rondeau also served as the 46th Test Group Executive Officer where he continued his role as an airborne test conductor. Next, he was selected to attend the Air Force Institute of Technology and later was selected to attend the Air Force Test Pilot School. Upon graduation, Rondeau served as a flight commander, the Chief Flight Test Engineer, and an Assistant Director of Operations for the 419th Flight Test Squadron, performing flight test on the B-1, B-2, and B-52. While at Edwards AFB, he was trained and qualified as a member of the Joint Combat Assessment Team which provided combat forensic analysis to deployed forces worldwide. He was next assigned to the Special Programs Division, Fighter/Bomber Directorate where he served as the Chief of Test and Program Manager. Prior to his current assignment, Rondeau served as a test squadron commander where he led a unit of 130 people and was responsible for a $350M portfolio of ground, air, space, and cyber threat weapon systems. Across his assignments, Rondeau has over 300 flight hours as a flight test engineer in 34 different aircraft with qualifications in B-1B, B-52H, C-12J, HH-60U, and F-16D. In his current role, he is also appointed an Assistant Professor of Electrical Engineering.

AFIT Welcomes Isbill as New Commander and Director of Staff

Col. Sarah Isbill

Col. Sarah Isbill assumed command of Air University Detachment 1 at the Air Force Institute of Technology in June 2022. As the senior military leader, she is responsible for the good order and discipline for approximately 1,800 active duty faculty, staff, and students. In addition to her commander duties, Isbill serves as the director of staff at AFIT where she leads the strategic vision and tactical decisions of the Institute.

Isbill entered the Air Force in 2001 after graduating from the United States Air Force Academy with a bachelor's degree in chemistry. Her career has included security forces assignments at several locations, as well as a teaching assignment at USAFA. While assigned to Wright-Patterson Air Force Base as an action officer at Headquarters Air Force Materiel Command, she earned a master's degree in chemistry from Wright State University in 2011. She has also served on deployments to Iraq, Pakistan, Afghanistan, and Kuwait.

AFIT is the Department of the Air Force's leader for advanced, multi-disciplinary academic education and technical professional continuing education. A component of Air University and Air Education and Training Command, AFIT employs more than 750 military and civilian faculty and staff members and manages a $224.2M annual budget. AFIT provides professional continuing education for nearly 36,000 students and graduate education to more than 1,000 students annually. In addition, AFIT's Civilian Institutions Program Office manages approximately 2,500 students enrolled in a variety of health profession programs and another 1,000 line, legal and chaplain officers enrolled in various programs at leading civilian universities and research centers.

AFIT Assists USAFA to Develop Enlisted Faculty Program

The Air Force Institute of Technology recently assisted the U.S. Air Force Academy to develop a program to hire qualified enlisted officers to teach STEM-based curriculum to cadets. The program features senior noncommissioned officers with the teaching credentials and advanced academic degrees required of all faculty members.

Additionally, AFIT alum **Master Sgt. James Earley** (MS Systems Engineering, 2022) is one of the 10 enlisted instructors; teaching behavioral science and leadership at USAFA.

U.S. Air Force Academy photo

Master Sgt. Bonnie Rushing, a military and strategic studies instructor at the U.S. Air Force Academy, is a member of the school's Enlisted Faculty Program.

AFIT, USAFA Partner with Thai Ministry of Defence

The Air Force Institute of Technology and the U.S. Air Force Academy partnered with the Thai Ministry of Defence on an information exchange agreement project titled "Remote Sensing for Base Perimeter Defense." It is the first such agreement between the U.S. Department of Defense and Thai Ministry of Defence.

"The primary area of mutual technical interests was development of a system and algorithm for human detection for base security, especially in situations where traditional measures such as video may not work well like poor illumination, or obscuration by foliage," said Dr. Richard Martin, professor of electrical engineering at AFIT.

The agreement will allow both parties to advance the theory and testing needed for systems that can sense, detect, and classify installation threats. Commercial off-the-shelf prototypes from both Thailand and the U.S. will be tested, and feedback shared.

Col. Ryan Thomas, a professor at USAFA at the time, saw the topic on a list of proposed research collaborations by Thailand. The scope of the project was similar to work he had done with Martin during a prior assignment as faculty at the AFIT. Martin and Thomas developed a prototype system, signal processing model, and imaging algorithm using a radio frequency wireless sensor network for detection and tracking of humans, including through-wall situations. That research made the collaboration with Thailand a natural fit.

"After meeting with my Thai counterparts recently, I am very excited to begin this collaboration," said Lt. Col. Neil Rogers, USAFA senior military faculty and assistant professor of electrical engineering. "I believe we have much to learn from one another and can help move the state-of-the-art forward in high-priority areas of counter-Unmanned Aircraft Systems research and base perimeter security."

"The Thai partners will bring valuable contributions, including an understanding of the effects of challenging outdoor environments on radio sensor networks and an understanding of real-world tactical issues that need to be addressed for base security applications," said Martin.

AFIT has a history of partnership with the Thai Ministry of Defence dating back to the late 1970s when four Thai students earned master's degrees and four attended professional continuing education courses.

Dr. Nils Wagenknecht, German administrative and professional personnel exchange officer at the Air Force Institute of Technology and Dr. Walter Jones, AFIT director and chancellor.

U.S. Air Force photo by Katie Scott

AFIT Partners with University of the German Armed Forces Munich

Dr. Walter Jones, Air Force Institute of Technology director and chancellor, signed a Letter of Accord to Collaborate between AFIT and the University of the German Armed Forces Munich (UniBw Munich) on 12 July. The goal of the collaboration is to develop research and academic partnerships in disciplines of mutual interest such as electrical and computer engineering, technology, space, cyber, and operations research.

Both universities recognize the importance of academic exchanges in terms of teaching and research, as well as the special opportunities provided through contacts between faculty and students. This is the first arrangement between AFIT and a German university.

"We have valued our collaborations with Germany, both bilaterally and through our NATO partnership, for many years. This agreement takes that collaboration to another level by enabling joint efforts in teaching and research between two top military-focused universities," said Jones. "I look forward to working with our University of the German Armed Forces Munich colleagues for years to come."

Dr. Andreas Knopp, professor of satellite communications technologies at UniBw Munich, coordinated the conclusion of the Letter of Accord that will commence in the field of electrical and computer engineering.

"We are pleased with the closer cooperation and the new opportunities to collaborate on scientific and educational level," said Knopp who is also a chair holder of signal processing and the director of the Munich Center of Space Communications research facility at UniBw Munich.

The partnership was brokered by Dr. Nils Wagenknecht, a contracts lawyer for the Federal Ministry of Defense in Germany. He joined the AFIT team in 2021 for one year under the Administrative and Professional Personnel Exchange Program between the German Federal Defense Administration and the U.S. Armed Forces where he serves as an executive staff member working to identify education exchange opportunities between AFIT and German universities.

"The arrangement establishes a win-win relationship for both institutions. I am delighted to be able to accomplish this joint international partnership during my time at AFIT," said Wagenknecht. The Letter of Accord will also enable faculty to explore additional forms of scholarly collaboration including certificates, seminars and conferences, and the exchange of relevant academic materials.

Located in Neubiberg, Germany, the University of the German Armed Forces Munich is recognized by the State of Bavaria as an institution of higher education within the area of responsibility of the Federal Ministry of Defense. It provides future officers with an opportunity to pursue civilian higher education. The core tasks comprise academic teaching, research as well as technology and knowledge transfer.

ROTC Cadets Arrive at AFIT for Annual ACE Program

AFIT's Air Force Cyberspace Technical Center of Excellence (CyTCoE) and Center for Cyberspace Research's (CCR) annual Advanced Cyber Education (ACE) program welcomed 31 cadets to the AFIT campus 12 July to 5 August, 2022. After the COVID pandemic cancelled the 2020 offering, and required a virtual offering in 2021, ACE leaders were excited to resume the traditional in-person course in 2022.

ACE is a four-week summer course targeted to Reserve Officer Training Corps (ROTC) cadets between their junior and senior years in college. The objective of the program is two-fold; to develop the next generation of cybersecurity leaders through an intense program that immerses undergraduate students in the cybersecurity discipline, and to grow new cyber officers into future military leaders.

This year's cadets hailed from a multitude of STEM degree programs from ROTC detachments across the United States and included 18 Air Force ROTC cadets and 13 Army ROTC cadets.

The ACE program covers cybersecurity related topics such as network fundamentals, forensics, reverse engineering, industrial control system security, and avionics vulnerability identification and mitigation. Moreover, the course introduces the student's cyberspace operations to include both defense and offense. The course culminated in a "Hackfest" showcasing the future cyber operators newly acquired knowledge to defend "their" network, (built, hardened, and protected by individual teams), while attacking five other teams' networks who also actively defend their network in a winner-take-all capture the flag event. Upon completion, Col. James Fee, Graduate School of Engineering and Management Associate Dean, presented the graduates with their certificates and recognized them for their outstanding achievements.

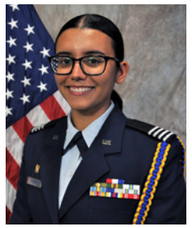
U.S. Air Force photos by Mark McDonald

LEFT: ACE cadets participate in Battlespace Next (BSN) serious game play.

BELOW: Cadets tour the National Museum of the U.S. Air Force on Wright-Patterson AFB.

To learn more about ACE, visit www.AFIT.edu/ACE

WHAT THE CADETS ARE SAYING



"I walked into this program hoping to expand my cybersecurity knowledge and learn more about career opportunities. The professors not only shared their expertise, but also inspired us to continue to explore and challenge our critical thinking skills."

—Cadet Colonel Veronica Vergara, Rutgers University, Detachment 485

"This program offers a unique experience that you can't find anywhere else. It opened my eyes to how vast the world of cyber is. ACE is a technical playground that allows cadets to showcase their skills through a collaborative and immersive environment."

—Cadet Colonel Brenden Hale, Kent State University, Detachment 630

Faculty Academic Promotions

The Air Force Institute of Technology's Graduate School of Engineering and Management has completed the academic year 2021-2022 promotion and tenure cycle. Six faculty members underwent a rigorous evaluation of their teaching, scholarship and service resulting in a promotion in academic rank.

By Stacy Burns I Air Force Institute of Technology

Dr. Brett Borghetti
Professor

Dr. Brett Borghetti earned promotion to Professor of Computer Engineering within the department of Electrical and Computer Engineering. His research interests include adaptive algorithms, artificial intelligence and machine learning, artificial neural networks, computational mathematics and optimization, human factors engineering and human systems integration.

Borghetti has demonstrated excellence in the 28 courses he has taught to over 500 students since 2008. He has advised 31 M.S. and seven Ph.D. students (four complete, three in-progress). He has contributed to two book chapters; 28 peer-reviewed journal articles; 35 peer-reviewed conference papers (including abstracts) and supported 28 funded research projects totaling $3.03M ($1.46M in personal funding).

Awards recognizing his teaching and scholarly activity include: AETC Educator of the Year (civilian category, 2021); Graduate School of Engineering and Management nominee for Ezra Kotcher Teaching Award (2021); Eta Kappa Nu Outstanding Instructor of the Year (2014, 2018); and AETC Winner of the Air Force STEM Outstanding Science and Educator Award (2015).

Dr. Scott Graham
Professor

Dr. Scott Graham earned promotion to Professor of Computer Engineering within the department of Electrical and Computer Engineering. His research interests include security at the intersection of real physical systems and the computers that control them. Specific areas of interest include cyber physical systems security, embedded security, computer communication networks, and vehicular cyber security.

Graham has contributed to 26 peer-reviewed journal articles; 59 peer-reviewed conference papers; and 14 book chapters. He has supported 15 funded research projects totaling over $2.1M, including $696K in personal funding; and advised 37 M.S. (33 complete, four in-progress) and seven Ph.D. students (three complete, four in-progress); and is a co-author on an awarded patent.

Among Graham's most notable services are: Director, AFIT Center for Cyberspace Research; Chairman, Graduate Cyber Operations Program Curriculum Committee (2017-Present); Chairman, ENG Faculty Search Committee (2016-2018); Principal Investigator, Cyber-Physical Systems Laboratory (2016-Present). He is a Senior Member of the Institute of Electrical and Electronics Engineers (IEEE).

Dr. Douglas Hodson
Professor

Dr. Douglas Hodson earned promotion to Professor of Computer Engineering within the department of Electrical and Computer Engineering. Hodson has taught all three classes within the software engineering sequence as well as an experimental design class and a course in microprocessor design.

Hodson's research focus concerns the software engineering aspects of Modeling and Simulation (M&S) architectures, frameworks, and paradigms. His research productivity includes successfully graduating 19 M.S. students, one Ph.D. and the administration of the selection and funding of a postdoc. He has also served on numerous AFIT M.S. and Ph.D. research committees.

Hodson's research has resulted in 39 journal articles, four book chapters and one book. In addition, he has authored 43 refereed conference papers and presented at numerous conferences. Hodson has been either the principle investigator (PI) or co-PI on 33 proposals from multiple sponsors that total over $4.150M.

Hodson has served as the Assistant Air Force Representative for the US/ROK alliance, which hosts the Defense Analysis Exchange every two years in Seoul, Korea.

Lt. Col. Samuel Butler
Associate Professor with Military Tenure

Lt. Col. Samuel Butler, Ph.D., USAF earned promotion to Associate Professor of Physics with military tenure within the department of Engineering Physics. Butler has taught 22 offerings of eight distinct courses from 2015 to 2021. He also taught nine offerings of two distinct refresher courses for incoming students, continually upgrading the material along the way. He has advised six MS theses and one Ph.D. dissertation, and has been or is currently a member of another seven MS thesis and one Ph.D. dissertation committees.

Butler has nine peer-reviewed journal publications and one peer-reviewed conference paper with an impact factor of 2.44. He has 14 conference proceedings, three conference presentations, 149 Google Scholar citations and an h-index of six and i10 index of five. Butler's total funded research since 2015 totals $354,279 ($339,459 as PI; $14,820 as co PI).

Dr. Anil Patnaik
Associate Professor with Tenure

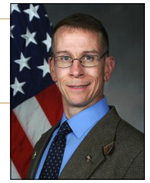
Dr. Anil Patnaik was awarded tenure at the rank of Associate Professor of Physics within the department of Engineering Physics. His research interests include the theory and experimentation of fundamental laser-matter interactions, both in the realm of classical and quantum regime, and their applications. He has worked on a wide range of topics in quantum optics, non-linear optics, laser-based diagnostics and state-of-the-art AF applications.

Patnaik taught eight offerings of four distinct courses from 2019-2021. He co-developed and co-taught a 36-hour quantum information/ quantum computing short course in 2020. He received the Graduate School of Engineering and Management Teaching Award in 2021 and serves as the curriculum chair of the Applied Physics program. Patnaik's research partnerships resulted in AFOSR funding and MOU/MOA between AFIT and AFRL/RQ for operational lease of Extreme Light Laboratory.

Patnaik has advised three M.S. theses and is currently advising four Ph.D. dissertations. He has also been or is currently a member of four M.S. theses and four Ph.D. dissertation committees. Since 2019, Patnaik has obtained over $816K in research-grant funding and has published five archival journal articles.

Overall, Patnaik has over 43 peer-reviewed publications and another six currently in preparation. He's had two book chapters published while at AFIT and has published 28 proceedings papers. While at AFIT, Patnaik and his students have made 16 conference presentations and he or one of his students has given 11 invited talks.

Dr. Jeremy Slagley
Associate Professor with Tenure



Dr. Jeremy Slagley earned promotion to Associate Professor of Industrial Hygiene and Environmental Science with tenure within the department of Systems Engineering and Management.

Slagley's research interests include modeling and experimental studies in support of Chemical, Biological, Radiological, and Nuclear (CBRN) contamination, decontamination, and control, energy, waste management, and ototoxic chemical effects in the Department of Defense workforce.

Slagley teaches courses in risk assessment, evaluation, and control, as well as systems safety, and human factors engineering. He has successfully advised 32 AFIT theses and one doctoral dissertation at IUP. Slagley has served as Program Director and Curriculum Chair of the Industrial Hygiene Program and as the Program Director of the Countering Weapons of Mass Destruction Graduate Certificate Program.

Slagley has published 28 peer-reviewed journal articles, six peer-reviewed conference papers, and eight other publications. He has presented or co-presented 48 times at national and international conferences and 11 times at DoD or regional conferences. In the area of research since 2016, he has worked as principal investigator for $1.16M in research grants, and co-investigator for $1.35M in grants.

Slagley recently completed a Fulbright scholarship at the Nofer Institute for Occupational Medicine in Lodz, Poland.

LEARN MORE ONLINE

Read the full faculty promotion article in AFIT news:
www.afit.edu

Graduate School faculty bios:
Find out more about graduate school faculty and their research areas of interest.
www.afit.edu/bios

BY THE NUMBERS

Accumulative achievements by these six AFIT Graduate School faculty members:

380+ publications

146+ students advised

more than **$8.6M** in sponsored research funds

1 patent award

Publication Featured in AU Journal

Lt. Col. Robert Bettinger, Ph.D., USAF (Deputy Director of the Center for Space Research and Assurance and Assistant Professor of Astronautical Engineering) and **1st Lt. Adam Wilmer, USAF** (Ph.D., astronautical engineering) received publication of their paper, "Beyond the High Ground: A Taxonomy for Earth-Moon System Operations," in the *Air & Space Operations Review* (ASOR) Summer 2022 issue and the article was featured in the June 24 list of "Weekend Reads" by SAF/PA.

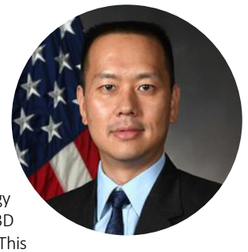
READ THE ARTICLE ONLINE
https://go.usa.gov/xJXyQ

STAT Center Recognized for Outstanding Performance

The International Test and Evaluation Association has recognized AFIT's Scientific Test & Analysis Techniques Center of Excellence (STAT COE) along with portions of Air Force Life Cycle Management Center, specifically the T7 Program and Life Support System STAQ Lab, as the recipient of the International Test and Evaluation Association Technical Achievement Award. This award recognizes an individual or group for outstanding achievement in applying instrumentation, information technology, modeling and simulation, time-space-positioning information, electro-optics technology, or other Test and Evaluation technology to cause a test and evaluation program to be better, faster, and less expensive.

Of particular note is the teamwork between Air Force Life Cycle Management Center's Daniel Robinson, Jessica Allen, Eziolisa Ositadimma, and 1st Lt. Jarett Sveum and STAT COE's **Wayne Adams** and **Emily Divis** as they worked on avoiding physiological events by correctly characterizing the life support system of our newest training aircraft, which is critical in assuring proper Airmen training and readiness for our Air Force.

Chandrahalim Receives 2022 SASE Professional Achievement Award



Dr. Hengky Chandrahalim, AFIT Assistant Professor of Electrical Engineering, was named the 2022 Award Winner in the Professional Achievement Category for the Society of Asian Scientists and Engineer (SASE). The SASE Professional Achievement Award is given to a highly-experienced, mid-career professional who has made significant discoveries, made important advances in his or her chosen career path, and is acknowledged as a leader of large initiatives.

Chandrahalim's research in microsystems engineering and nanotechnology has produced revolutionary techniques in microfabrication with the potential to address key Department of the U.S. Air Force needs and to solve large-scale societal issues related to health, environment, and communication. He has pioneered the development of two-photon nanofabrication technique to create 3D functional microsystems on virtually any substrates. This technique has enabled the realization of 3D freeform geometries that have nanometer-level precision. This technology has created breakthrough solutions for multipurpose sensing in spatially constrained applications, such as drones, fighter aircrafts, microsatellites, and autonomous under water vehicles. The originality and creativity in this line of research have resulted in seven patents and two other pending patents within the last 18 months only. The results of this research have been disseminated in 10 articles within the last three years and received an invited talk in the IEEE RAPID 2021 Conference.

In addition, Chandrahalim led a research team in exploiting the unique properties of quantum dots to enable nondestructive testing of materials. Applications that can make use of this technology are non-contact testing of aircrafts, ground vehicles, and ships. The most near-term use of this technology is a new strain gauge for quality control, 3D printing, and in buildings and structures. This non-destructive, non-contact technology also has the potential to compete against another optical 2D strain-sensing technology called digital imaging correlation (DIC). At about 8% of the cost of a DIC system, this could save the U.S. Air Force approximately $32 million when buying a single system for up to 386 squadrons. The results of this study have been published in multiple venues and received serious attention from news media, such as *Nanotechnology Now* and *IEEE Spectrum*. This work also received special mention from the editor-in-chief of *ACS Applied Materials & Interfaces*.

Furthermore, Chandrahalim has taken an initiative to train graduate student officers from different academic departments at AFIT in studying novel nanoelectronic-based paints to economically and accurately identify strain on aircraft parts. The team was selected as the finalist in the Air Force Materiel Command's 2020 Spark Tank Competition. This nanoelectronic technology enables the Department of the U.S. Air Force to quickly identify surface defects on aircraft through an easy-to-read surface map. This work attracted the attention of the Vice Chief of Staff of the USAF who encouraged the team to submit a follow-on research proposal in July 2021.

The Society of Asian Scientists and Engineers (SASE) is a non-profit organization dedicated to advancing Asian Americans in STEM to achieve their full career potential.

INNOVATION DESTINATION

It is a systems world and innovation requires a systems view of whatever we do. It is in this context that this issue of the *AFIT Engineer* focuses on innovation, particularly with respect to the role of humans in the pursuit of innovation. Because AFIT is an educational institution and our products are technically-educated people, I dare to affirm that innovation is part of AFIT's DNA. The students who graduate from the Graduate School of Engineering and Management continue the trend of innovation, for which AFIT has been known for over 100 years. I invite readers to tie the technical innovation articles in this issue to the people required for national defense needs.

New Opportunities and Research Supporting Resilient and Effective Space Order of Battle and Architecture

By Lt. Col. Robert Bettinger, Ph.D., USAF | Deputy Director, Center for Space Research and Assurance | Air Force Institute of Technology

Since its founding, the Center for Space Research and Assurance (CSRA) faculty and staff have endeavored to first meet the future space needs of the Department of Defense (DoD) and Intelligence Community (IC) by enhancing AFIT's research-based, space-focused graduate education programs through external sponsorship. Second, CSRA has amassed a cadre of technical experts in a diverse set of scientific and technological disciplines from across multiple academic departments to support a wide variety of space-centric research areas.

While the meaning of the first half of the Center's name – "Space Research" – explicitly identifies our central academic function, the second half – "Assurance" – corresponds to CSRA's guiding philosophy: the recognition that space-focused graduate education and research will enable the formulation of innovative solutions to meet current and emergent defense and security challenges in the space domain. By advancing graduate space education with evolving courses and instructional content in AFIT's Astronautical Engineering (GA) and Space Systems (GSS) programs, developing graduate certificates in Space Systems and Space Vehicle Design to meet the continuing education needs of our Total Force, or connecting our master's and doctoral students with defense-focused research opportunities, CSRA provides the innovation necessary to address the Secretary of the Air Force's first Operational Imperative: "defining resilient and effective space order of battle and architecture."

Over the past decade, the defense and general security challenges facing U.S. space operations have steadily transitioned away from the classical paradigm of virtually uncontested near-Earth missions centered on supporting and enhancing the precision and lethality of terrestrial forces. Now, this paradigm is being supplanted by an ever-changing environment of peer/near-peer competition, the emergence of new state and commercial space actors, and the prospect of contested operations in not only the traditional orbital regimes spanning low-Earth to geosynchronous orbit, but also the cislunar domain. CSRA, through the technological acumen of its faculty and staff, and the leadership of directors, has adapted to the developing challenges of the space domain and remains one of the recognized leaders in space research and innovation.

Continued on next page

Resilient Space Order of Battle and Architecture

Continued from page 11

Currently, CSRA pursues research in fields that directly support the technological and analytical foundations of U.S. space operations, with thrust areas including:

- CubeSat bus and payload design, development, and test to enable the fielding of low-cost, responsive space platforms.
- Advanced electric and green space propulsion system development and testing.
- Space architecture modeling, simulation, and analysis for near-Earth and cislunar missions associated with Space Domain Awareness, space control, and space-based logistics.
- Orbital engagement and spacecraft survivability analysis supporting the concept of space as a warfighting domain.
- Additive manufacturing for space applications.

Although CSRA is managed by its faculty and staff, the core research is performed by its affiliated graduate students from the Department of Aeronautics and Astronautics, as well as from across AFIT. In 2021, the type of available graduate programs expanded with the introduction of the Accelerated Space Systems Engineering (AGSS) degree, a program designed to grant student's in the Awaiting Pilot Training (APT) program a Master's of Engineering following the completion of one-year of course work and a capstone project.

All student research positively impacts the continued innovation of U.S. space capabilities through analysis, simulation, or experimentation, and can take the form of a thesis, dissertation, or even a published scholarly journal or conference publication. Several of the articles on the following pages highlight current graduate student research and the center's dedication to ensuring effective and resilient space operations. This research, which represents only a small fraction of the wide research portfolio pursued by CSRA faculty and students, examines different ways in which U.S. space operations can be enhanced by examining different modes for spacecraft attitude control, new methods for conducting Space Domain Awareness, and fatigue life prediction of additively printed aerospace parts.

Tuning of a Logarithmic Barrier Potential Function Control Law in the Presence of Attitude Constraint Zones

By 2d. Lt. Brendan Hennessey Rose
APT GA Student
Air Force Institute of Technology

The need for procedures that incorporate accurate spacecraft attitude slewing techniques in order to protect mission objectives, as well as instrument safety, is vital in effective spacecraft operations. Many spacecraft reorientation maneuvers involve multiple mission constraints such as maintaining communication with ground stations, ensuring solar arrays point toward the sun, or protecting sensitive equipment from bright objects. Due to the multiple constraints that must be enforced during a typical slew maneuver, mission planning is a complex task that is often accomplished by ground operators. In order to improve agility and responsiveness of DoD space systems, this research investigates a computationally efficient feedback control algorithm that can achieve on-board attitude maneuver planning, while adhering to specified mission constraints.

This research implements a logarithmic barrier potential function-based feedback control law, allowing the user to specify both mandatory and forbidden pointing directions. The control law was developed in previous literature, however the sensitivity of the solution to various tuning parameters was lacking. This research fills this gap by analyzing the controller's performance for a variety of scenarios. The end goal of this project is to identify control tuning parameters that lead to desired performance in terms of pointing accuracy and expended control effort. In particular, three cases are analyzed – a single forbidden zone, a single mandatory zone, and a combination of a forbidden zone and a mandatory zone. Fig. 1 depicts a 90-degree attitude slew maneuver in the presence of a 30-degree attitude forbidden zone, projected onto a 2D plane for visualization purposes. The solid red line represents the trajectory of the sensitive instrument boresight vector which is not allowed to enter the shaded gray area, representing the forbidden zone. These results clearly show that changing the tuning parameters, 'a' and 'k', has a drastic effect on the solution. The overall trend shows that increasing 'a' results in a smoother trajectory, while decreasing 'k' severely increases the error in the final attitude (i.e. the 'x' marker is further away than the desired '+' marker in the figure). In all cases, however, the logarithmic barrier potential function is successful in adhering to the forbidden zone constraint. This analysis can inform operators on appropriate tuning parameters that should be chosen for a particular mission. For example, for the mission depicted in the accompanying figure an operator would select 'a=8.5' and 'k=0.05' as the most desirable option. Once these parameters are appropriately selected, the attitude mission planning can be accomplished autonomously on-board the spacecraft, significantly reducing the workload on ground operators.

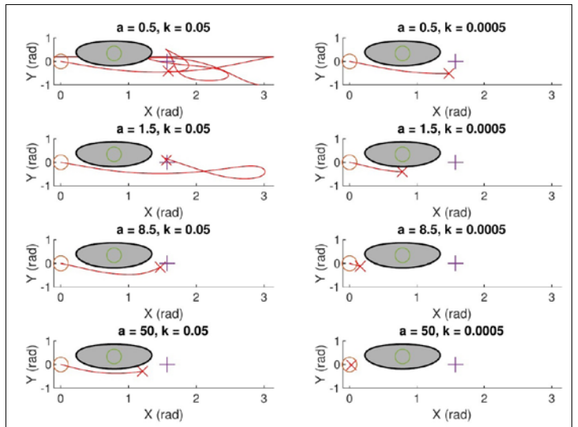
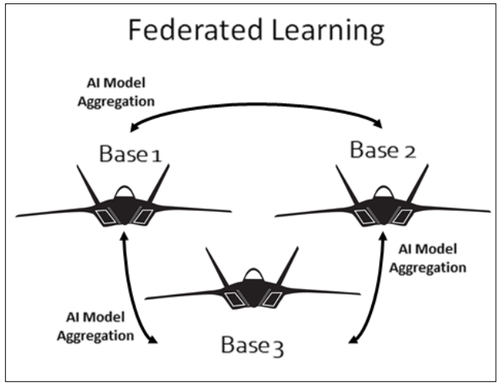


Fig. 1

Federated Learning Enhances Resilient Basing

By Capt. Chancellor Johnstone, Ph.D., USAF
Air Force Institute of Technology



Under the Department of the Air Force's Seven Operational Imperatives, one emphasis is on "defining optimized resilient basing, sustainment, and communications in a contested environment." Resilient basing aims to reduce risk associated with forward basing in contested locations. Instead of focusing on decisions related to basing locations themselves, we aim to enhance resiliency associated with supporting infrastructure. We focus on a communication-efficient and resilient approach to the completion of artificial intelligence (AI) tasks to support operations of these forward bases through federated learning (FL).

Consider a scenario where mission data collected across a set of locations is centralized, i.e., stored at one central server. Obviously, the centralized nature of this information puts it, as well as any downstream tasks relying on this information, at risk; centralizing data is inherently non-resilient. Federated learning is a method of distributed computing that trains AI models without centralized data, thus eliminating the risk of a single point of failure. Model training occurs at distributed nodes, i.e., the individual forward operating bases, with local data. These individual models are then aggregated together to construct a global model. The data and AI tasks are no longer susceptible to any single point of failure, but rather become more resilient as the number of basing locations increases. With a FL-based approach to the completion of AI tasks in a contested environment, we can drastically reduce risk.

Federated learning is currently an important topic in the AI and machine learning (ML) community. In response to this, a consortium of AFIT faculty members and students across multiple departments is taking part in a variety of education- and research-based initiatives. One of these initiatives is the construction of a graduate level course which explores topics crucial to FL. These topics include a theoretical introduction to ML, FL in practice, strengths and weakness of various FL approaches, and privacy-preserving ML. The course also includes a hands-on project involving the development of a federated model to detect human activity using image data collected from geographically separated and secured edge devices. A second initiative involves multiple research lines associated with the theory and applications of FL to include uncertainty quantification in FL, digital health analysis using wearables, e.g., a Fitbit, and Parkinson's severity prediction using sensitive user data.

CIE Set to Launch Tech-focused Faculty Learning Community

Since its creation in October 2021, the Center for Innovation in Education (CIE) has provided a variety of development services to AFIT faculty, students, and staff, with plans to expand these offerings in Fall 2022. The CIE hosts frequent "Lunch and Learn" events and workshops as well as writing lab consultations and education technology support online and in person. In response to feedback from focus groups, the CIE will soon launch a technology-focused Faculty Learning Community (FLC) this fall under the direction of **Jonathan Zemmer**, Educational Technology Liaison.

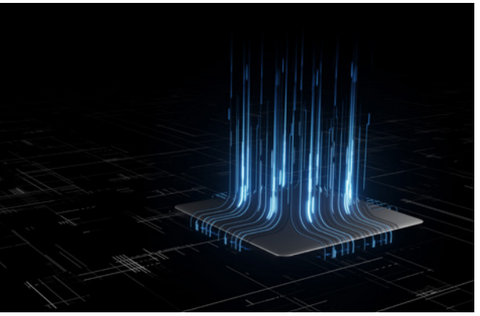
FLCs have attracted attention in higher education circles for many years as ways to implement meaningful teaching and learning change. As faculty with a shared interest in a new concept, problem, or set of teaching tools, the members of an FLC commit to meet on a scheduled basis for a defined period of time – typically an academic year – and work together to meet self-directed goals. Ultimately, participants implement a novel teaching concept or tool, meet to discuss their experiences and share ideas, and report outcomes and impact to their broader teaching community.

While existing research on FLCs suggests many benefits for faculty, students, and institutions, the CIE hopes to add specific insight into their potential within military educational environments like AFIT. Specifically, Mr. Zemmer plans to show how implementing new forms of educational technology can improve teaching and student outcomes. "FLCs like ours," he says, "can provide a mechanism for understanding faculty experience as they utilize technology across diverse learning environments."

At AFIT, the first FLC will take place from Fall 2022 to Summer 2023. The group will explore how FedRAMP-approved technologies available in the AF ecosystem can be used to meet specific teaching and learning needs within our community. The CIE also plans a showcase event during which FLC faculty can present their experiences, describe their technology implementation, and share their recommendations. This event will provide a capstone to each member's experiences and also allow them share resources and insights with the broader AFIT and Air Force community.

Faculty interested in participating in this fall's educational technology FLC should e-mail cie@afit.edu for more information.

Microelectronics Seminar for the Intelligence Community Presented by AFIT Assistant Professor



AFIT's Department of Electrical and Computer Engineering hosted the seminar "Microelectronics 101 for the Intelligence Community" on 21-22 June at the AFIT campus. The two-day seminar, taught by Maj. Timothy Wolfe, Assistant Professor of Electrical Engineering, provided a short course on the fundamentals of integrated circuit and semiconductor device physics, operating principles, and fabrication technology at a graduate survey level. A majority of the 35 attendees were able to participate in person with the rest joining online. Participants were from the National Air and Space Intelligence Center (NASIC) as well as a variety of other intelligence community organizations from across the country and federal government.

Development of Course Content

This seminar, a first of its kind, was developed following the introduction of Wolfe to a group of intelligence community members by a long-time collaborator. This introduction led to a series of meetings on the topic of microelectronics technology. During those meetings, Wolfe discovered a strong desire from the intelligence community to gain more formal education in the area of microelectronics. These productive meetings led Wolfe to propose a more formal presentation for a larger audience that could benefit from an in-depth, two-day seminar on microelectronics, without committing to a full-time graduate degree.

As Wolfe and his initial intelligence community collaborators suspected, there was strong enthusiasm for such an offering. This enthusiasm ultimately led to expanding the seminar to include a tour of portions of the Air Force Research Laboratory Sensors Directorate, to further broaden the attendee's exposure to expert knowledge and forge subject matter expert network connections. As a result of this initiative, the Department of the Air Force, Department of Defense, and other federal entities are benefiting from analysts and managers who are better able to interpret data, make meaningful recommendations, and guide leadership in important policy decisions as they relate to microelectronics technology. In the short-term, the new knowledge and education have led to immediate and actionable information to inform on-going analysis; in the long-term, this education will serve as a baseline for future project analysis in addition to the future possibilities created through professional networking fostered by this seminar.

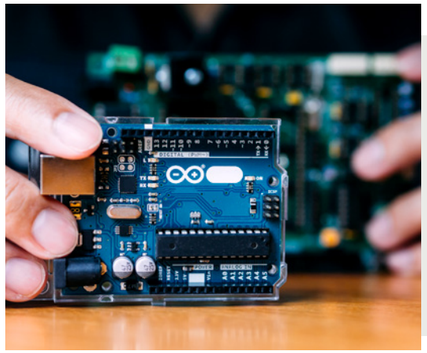
Hybrid Delivery Option

The course greatly benefitted from a hybrid style of teaching which allowed the participation of numerous individuals unable to travel. The course marks AFIT's inaugural offering of non-degree seeking microelectronics education for working professionals.

Expanded Future Offerings

The overwhelmingly positive feedback received from participants has motivated Wolfe to begin planning future offerings of the seminar while considering expansion into additional topics in Electrical Engineering. Other AFIT faculty who share Wolfe's passion for proliferating their subject matter into the operational and intelligence community through a non-degree format are encouraged to contact Wolfe to discuss future initiatives.

Maj. Timothy Wolfe, Ph.D., USAF, is an Assistant Professor of Electrical Engineering within AFIT's Department of Electrical and Computer Engineering. For more information, he can be reached at timothy.wolfe@afit.edu.



"The content of the course was extremely relevant to our team's mission...the course was a good blend of information and high-level material (while keeping it to a level where non-technical people could still comprehend). It was advanced enough to be valuable for the work that we do, while being simple enough. We believe that this course and this kind of content is helpful throughout the IC and specifically to what we do on a daily basis."

—Microelectronics Seminar Student

Fatigue Life Prediction of Additively Printed Aerospace Parts

By Maj. Daniel Miller, Maj. Ryan Kemnitz, Ph.D., USAF and Dr. Ramana Grandhi, Air Force Institute of Technology and Dr. Luke Sheridan, Air Force Research Laboratory (AFRL/RQTI)

Major Daniel Miller, Astronautical Engineering Ph.D. student within AFIT's Department of Aeronautics and Astronautics, developed a method to define the inspection criteria for Additively Manufactured (AM) components shown in Fig. 1. The research furthered the ability to develop short life systems to augment our high-end platforms as outlined in the Air Force Science and Technology Strategy 2030 by connecting naturally created defects to component life through the location and mission requirements.

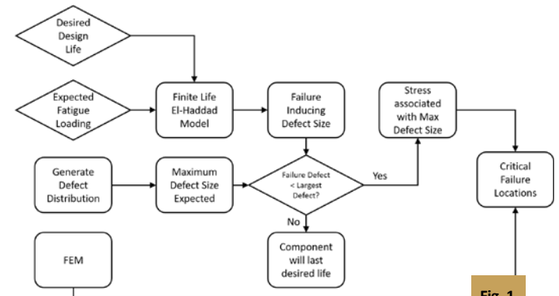


Fig. 1

Process flow to predict minimum defect size of interest and potential failure regions.

Fatigue life modeling allowed for the prediction of minimum defect sizes that can lead to failure for a desired mission life. By applying the worst case defect size, a minimum stress level was identified that could contribute to early failure (Fig. 2). Linking the model with Finite Element Analysis (FEA) enabled geometry dependent predictions of where cracks will start to form. Combined, the method generates an inspection resolution and search area for a given material, geometry, and mission.

To validate the method, high temperature metal structures were printed at AFIT through the Additive Manufacturing Lab (AniMaL) shown in Fig. 3. Collaboration with the Air Force Research Laboratory (AFRL/RQTI) Turbine Engine Fatigue Facility (TEFF Lab) enabled the characterization of material properties and failure testing of the hardware through a series of design lives and load cases. The research resulted in three conference presentations [1-3] and two peer reviewed journals [4, 5]. The TEFF Lab will continue to refine the method, enabling the certification of AM parts for limited life flight missions.

Maj. Miller will continue his career at the United States Air Force Academy (USAFA) as a faculty member of the Astronautical Engineering Department. Through continued collaboration with AFIT's Department of Aeronautics and Astronautics, this method will enable further mass reductions in satellite structures by certifying AM components to survive launch while accounting for naturally formed defects.

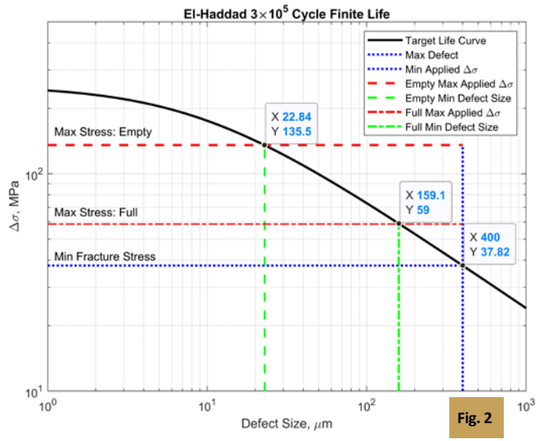


Fig. 2

The minimum predicted defects sizes (green) that could lead to failure within 3 x 10^5 cycles fatigue life and the maximum stress for two different configurations. The minimum stress (blue) to cause fracture within 3 x 10^5 cycles of fatigue life for the maximum defect size of 400 µm.

References

[1] Miller, D., Kemnitz, R., Grandhi, R.V., Sheridan, L.C., Fatigue Life Modeling and Experimental Validation of Additively Manufactured Turbine Blade with Respect to Defect Size and Location, *AIAA SciTech Forum*, San Diego, CA, January 2022.

[2] Miller, D., Kemnitz, R., Grandhi, R.V., Sheridan, L.C., Fatigue Life Model Using Defect Size, Stress, and Life Validated by Axial and Bending Vibration Testing, *AIAA Aviation Forum*, Chicago, IL, June 2022.

[3] Miller, D., Kemnitz, R., Grandhi, R.V., Sheridan, L.C., Fatigue Life Predictions of Additively Manufactured Components for Satellite, *Small Satellite Conference*, Logan, UT, SSC22-WKI-02, August 2022.

[4] Miller, D., Kemnitz, R., Grandhi, R.V., Sheridan, L., "Toward Digital Twin Development for Additively Manufactured Turbine Blades with Experimental and Analytical Methods," *Journal of Structural and Multidisciplinary Optimization*, Springer Nature (accepted), 2022.

[5] Miller, D., Kemnitz, R., Grandhi, R.V., Sheridan, L.C., "Fatigue Life Modeling and Experimental Validation of Additively Manufactured Turbine Blade with Respect to Defect Size and Location," *AIAA Journal*, (accepted), 2022.

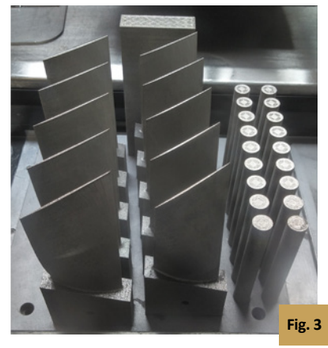


Fig. 3

Ten turbine blades and eighteen fatigue bars printed from IN718 on the AFIT M2Cusing Powder Bed Fusion printer.

Decision Support Tools for Adaptive Basing in PACAF AOR

Adaptive Basing is a concept for agile combat in peer-to-peer environments that is a Department of Defense (DoD) initiative. The concept relies upon suitability of existing infrastructure in locations that are favorable to the DoD. There are a significant number of variables in adaptive basing decisions ranging from distance to target, political relationship with host country, available materials and equipment, existing airfield size, etc. AFIT Department of Systems Engineering and Management faculty joined a research collaboration with the USAF's primary stakeholders in adaptive basing strategy—The Rapid Engineer Deployable Heavy Operational Repair Squadron Engineers (RED HORSE).

The research collaboration team, including **Capt. Zachary Moer, Lt. Col. Steven Schuldt**, and **Dr. Christopher Chini**, built a framework to establish a ranking system for airfields within the Pacific Air Force (PACAF) Area of Operations (AOR). Utilizing Analytical Hierarchy Processes (AHP), Capt. Moer synthesized multiple indicators, sourced from open source unclassified intel, to develop a framework for site selection. The framework includes indicators such as construction equipment availability, airfield length, available water resources, and political stability to rank all airfields. A total of 576 airfields were evaluated through multi-attribute utility theory and the pairwise comparison process within AHP (AHP). The synthesized indicator were then presented with GIS to provide an overall perspective of the potential adaptive basing locations (Fig. 1).

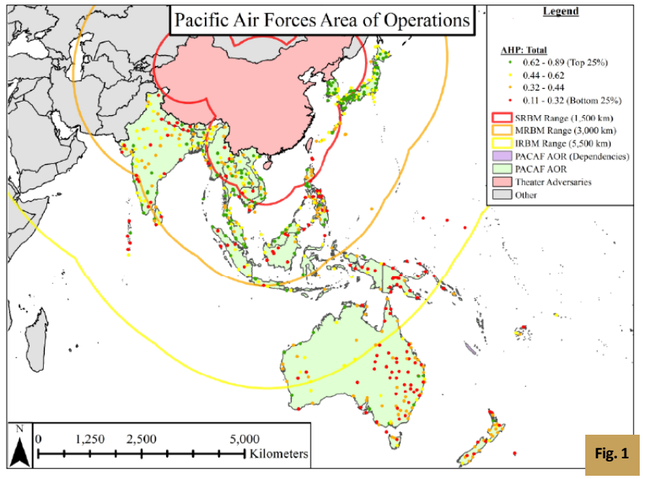


Fig. 1

One of the most limiting constraints was the range of missiles. Limiting potential airfields with the medium or intermediate ballistic missiles, significantly reduces the number of available options in adaptive basing environment.

The developed framework utilizes surrogate data to demonstrate its capabilities in a open-source platform. However, the framework was built to be flexible and adaptive to allow for new data or shifting priorities in site selection. The methodology has applications in right-of-boom scenarios to provide reactionary decision-making capabilities for adaptive basing. Additionally, the framework is suitable to help guide strategic or just-in-time decision-making, including wargaming or driving increased political-military engagement at strong candidate locations. The flexible and scalable nature of the framework and its methodology offers planning capabilities at multiple strategic levels.

Further results of the analysis and a more detailed description of the model are under consideration for publication in Air University's *Air & Space Operations Research* journal.

AFIT Answers SECDEF Call for Climate Resilience

The Department of Defense has prioritized climate change preparedness, describing it as "reshaping the geostrategic, operational, and tactical environments" (DoD Climate Risk Analysis, Oct. 2021). The Graduate of Engineering Management (GEM) program at AFIT prepares the Air Force Civil Engineer community to manage the infrastructure of the present against the threats of the future. The Engineering Management faculty have reshaped the GEM program curriculum to meet these expectations and developed a climate research focus within the program. Specifically, resilient engineering and asset management courses are geared towards managing risk and enhancing resilience of installation infrastructure.

In response to sponsors and constituents asking for research on climate change, GEM program faculty created an online special collection of DoD focused climate research found at **https://scholar.afit.edu/climate/**. This collection will be continually updated with student theses and published journal articles from the program. Currently there are 14 submission in the collection, with 10 more studies to be added this year. The collection has enhanced discussions with stakeholders including the Secretary of the Air Force for Environment, Safety, and Infrastructure (SAF/IEE) on AFIT's ability to tackle critical climate research for the DoD mission.

For example, a recent study led by **Lt. Col. Justin Delorit** and his student, **Capt. Sarah Brown**, evaluated the influence of climate on technical performance of built infrastructure, contributing to life cycle understanding of infrastructure. Additionally, the GEM faculty published an effort to understand how seasons of no-heat and no-cool might shift at installations around the country, impacting the timeline of maintenance of building conditioning systems. Student theses have investigated infrastructure risk to intensify hurricanes, changes in energy demand with a warming climate, and airfield flooding with sea level rise. **Capt. Scott Weiss**'s thesis investigated how Wright-Patterson AFB's electricity use could increase significantly, adding nearly $8M to the annual electricity budget, by the end of the century without any efficiency or climate upgrades.

The GEM program is well equipped to tackle the infrastructure questions of the future with increased climate vulnerability. The research stream, led by **Dr. Christopher Chini**, will be investigating drought implications on Western Air Force Bases, coastal infrastructure risk, resource impacts from climate change, and other relevant DoD climate issues in the coming years.

Orbit Determination with Event Based Cameras to Improve Space Domain Awareness

By 2d. Lt. Conor Wisentaner
APT GSS Student
Air Force Institute of Technology

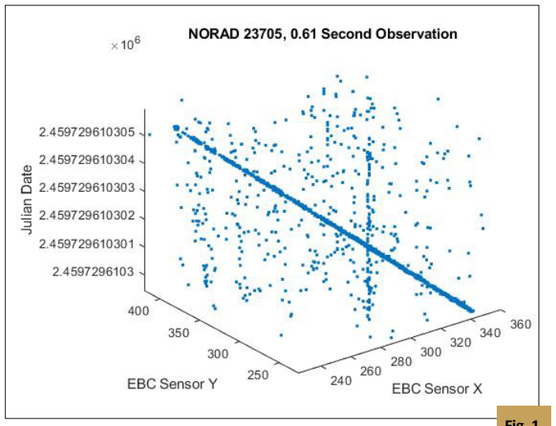


Fig. 1

Expanding surveillance into the space domain can provide data that could potentially increase our capabilities to meet current and future U.S military objectives. The document *Spacepower: Doctrine for Space Forces* outlines that Space Domain Awareness (SDA) "leverages the unique subset of intelligence, surveillance, reconnaissance, environmental monitoring, and data sharing arrangements that provide operators and decision makers with a timely depiction of all factors and actors — including friendly, adversary, and third party — impacting domain operations." As a result, sensor capabilities to accurately search, detect, track, and catalog resident space objects are critical to ensuring that U.S. space operators are able to adapt to the dynamic space domain and ensure a resilient Space Order of Battle. A core aspect of the "track" function is related to orbit determination, or the process of using sensor observations to continuously refine the orbit trajectories of objects in the catalog to prevent loss of custody. One way to capture data for orbit determination is through the use of Event Based Cameras (EBC) to provide position and time data points for objects of interest. This research focuses on comparing the accuracy of orbit updates produced by data points from an EBC to those produced by data from a traditional frame-based camera.

EBCs detect events on a per pixel basis any time a change in brightness is detected, such that a satellite pass observed by an EBC will generate hundreds of data points (Fig. 1) while a frame based camera observing the same pass would generate less than a dozen data points. This unique ability to produce many more data points per unit time makes EBCs theoretically well suited to produce high quality orbit updates from limited observations, despite having less spatial resolution than typical frame based sensors. Preliminary results indicate that the ability to generate more data points per pass makes up for this limitation and provides orbit updates that are typically more accurate than those produced by a frame based sensor observing the same pass. Potential future applications of EBCs for SDA include high accuracy single pass orbit updates and daytime satellite observations.

Cislunar Space Domain Awareness with Low-fidelity Sensors and Observer Uncertainty

By 2d. Lt. Joshua Block
APT AGSS Student
Air Force Institute of Technology

This research investigates the advantages of using multiple observation satellites to improve the accuracy of orbit estimation for target satellites in cislunar space. All spacecraft dynamics are modeled utilizing the Circular Restricted Three-Body Problem (CR3BP), with the observer spacecraft placed in an optimal Earth-Moon "touring" periodic orbit. The observers track a target object in an L1 Lagrange point-orbit as its proximity to the Moon makes it an ideal location both for communications platforms and a staging location for lunar operations. The periodic orbit was chosen based on its long-term orbital stability and close sweeps back to the Earth for better command and control. Another advantage of this orbit is its large coverage of cislunar space sweeping all the way out to the L3 Lagrange point.

To accomplish the goals of this research, the observer and target spacecraft are modeled in the synodic reference frame of the CR3BP as described above. We simulated optical sensors aboard the observing spacecraft in order to generate measurements with an angles-only approach, which are then utilized to initialize the orbit determination algorithm. With both the orbits and sensors modeled, the experiment then focuses on optimizing the number of spacecraft needed in the observing constellation to generate the same or less uncertainty than a tradition SDA network. Each spacecraft feature varying levels of both positional and measurement noise. The measurement data is then processed using optimal filtering techniques to generate the future positional data of the target spacecraft. Comparing estimated state data to the truth data generated by the model, each set of data is then assigned an error value which represents the primary metric used to contrast the different initial conditions set for each simulation. While this research focuses on its use for observing L1, it is worth noting that the contents of this research could be further applied to a larger application of Space Domain Awareness (SDA) and Space Traffic Management missions across the cislunar domain.

AFIT Alum Becomes First Woman in U.S. Navy to Lead Navy's Largest Developmental Air Wing

By Diana Stancy Correll

A woman is now commanding Naval Test Wing Atlantic for the first time.

Capt. Elizabeth Somerville, an EA-6B Prowler and EA-18G Growler naval flight officer, took command of the wing Aug. 11 during a ceremony at Naval Air Station Patuxent River in Maryland. She is tasked with leading the service's largest developmental air wing, which tests Navy and Marine Corps aircraft. The command is the "most technically diverse air wing in naval aviation," according to the service, and is composed of four squadrons that test and evaluate unmanned, rotary and fixed-wing aircraft.

"This test wing is charged with an important mission: Deliver lethality to our Sailors and Marines," Somerville said, according to a Navy news release. "It's a huge challenge, but this team is up for it — flight test is the ultimate team sport."

A U.S. Naval Test Pilot School graduate, Somerville previously deployed to support Operations Iraqi Freedom and Enduring Freedom in the Global War on Terrorism. During a 2011 deployment to U.S. 5th and 6th fleets, she served as the operations officer with Electronic Attack Squadron 141 for the Growler's first deployment aboard the aircraft carrier George H.W. Bush. She also previously served as the commanding officer of Air Test and Evaluation Squadrons 31 and 23.

U.S. Navy photo by Paul Lagasse

Capt. Elizabeth Somerville shakes hands with Marine Colonel Richard Marigliano after taking command of Naval Test Wing Atlantic during a ceremony at Naval Air Station Patuxent River Aug. 11.

"Over the past few years, this Wing delivered our Navy and Marine Corps capabilities, including Next Generation Jammer, the CH-53K heavy lift helicopter, and the Joint Air-to-Ground munition to name a few," Rear Adm. John Lemmon, Naval Air Warfare Center Aircraft Division commander, said during the ceremony, according to the release. "Its leadership and our people make this team world class."

Somerville relieved Col. Richard Marigliano, a CH-53 Stallion pilot who retired after 27 years of service.

"This tour was the most challenging and rewarding over my 27 years as a Marine," Marigliano said. "This test wing has big jobs ahead of us advancing naval aviation — [Capt. Somerville] is the right leader to move it forward."

Reprinted from NavyTimes.com.

> "This test wing is charged with an important mission: Deliver lethality to our Sailors and Marines. It's a huge challenge, but this team is up for it—flight test is the ultimate team sport."
>
> —Capt. Elizabeth Somerville, AFIT alum (M.S. Aeronautical Engineering, 2006)

AFRL Dedicates Parker Subsonic Research Facility (SuRF) to Beloved Engineer and AFIT Alum

By Johnathan Quinones and Whitney Wetsig
Air Force Research Laboratory Public Affairs

The Air Force Research Laboratory hosted a ribbon-cutting ceremony for its newest wind tunnel facility, July 7, 2022, and dedicated it to Dr. Greg Parker (Ph.D. Aeronautical Engineering, 2005), a beloved member of AFRL's Aerospace Systems Directorate, who died after a long battle with cancer. The Parker Subsonic Research Facility, or SuRF, is a low-speed wind tunnel used to evaluate prototype models including 3D-printed components.

Several AFRL leaders attended the ceremony including Chief Technologist Dr. Tim Bunning, Vice Commander Col. Joel Luker and Chief Master Sgt. Bill Fitch, AFRL Command Chief. AFRL Commander Maj. Gen. Heather Pringle provided opening remarks.

"This facility honors an aerospace engineer who made valuable contributions to AFRL," Pringle said. "The wind tunnel is going to advance aircraft designs that we see in our inventory years from now so the legacy of Dr. Greg Parker will be around for such a long time."

"This is truly an honor," said Davilyn Parker, Greg Parker's wife. "You have given us a way to see Greg from your point of view as a colleague, a coworker and a professional. You have shown us that he was respected, his work had value and that he made an impact."

U.S. Air Force photo by Rick Eldridge

AFRL's newest wind tunnel, the Parker Subsonic Research Facility, or SuRF, at Wright-Patterson AFB, Ohio. The facility is named after AFIT Alum Dr. Greg Parker (Ph.D. Aeronautical Engineering, 2005), a beloved member of AFRL's Aerospace Systems Directorate. SuRF is a low-speed wind tunnel used to evaluate prototype models including 3D-printed components that allows engineers to validate new aircraft designs.

Greg Parker, who worked for AFRL for 15 years, served active-duty Air Force for 20 years and retired as a major. He worked in test engineering for most of his career and was a senior engineer on AFRL's wind tunnel team for six years.

"[Greg] Parker was instrumental in bringing this facility to life," said Dr. Michael Gregg, director of AFRL's Aerospace Systems Directorate. "Today, the SuRF is available to support AFRL's demand for products, demonstrations and deliverables. It was designed to enrich AFRL core technical competencies especially in aerodynamics, aeroelasticity and rapid prototyping technology development in wind tunnel testing."

AFRL realized the need for this facility in 2015, and Greg Parker, chief engineer of the aero validation branch, advocated for funding and led the market research. AFRL facility engineers worked with 88th Air Base Wing civil engineers to design the tunnel, procure services and accomplish building modifications.

"The Parker SuRF frees up resources that would otherwise be tied up unnecessarily in the bigger tunnels in working out some of the earlier stages of proof-of-concept ideas," said Aaron Altman, technical adviser for the aerodynamic technology branch in AFRL's Aerospace Systems Directorate.

"It is deeply invigorating to see the physical manifestation of [Greg] Parker's vision, persistence and diligence come to fruition," Altman said. "There are a multitude of uses for the tunnel that have scientists chomping at the bit to get into the wind tunnel and start testing."

AFRL Commander Welcomes New Leader to Lab's Kirtland Site

By Jeanne Dailey
Air Force Research Laboratory Public Affairs

"He entered the Air Force Research Laboratory Space Vehicles Directorate as an Airman and is leaving as a Guardian," said Maj. Gen. Heather Pringle, commander of the Air Force Research Laboratory, as she began the change of command ceremony in which Col. Eric Felt, the Space Vehicles director and commander of the AFRL Phillips Research Site, relinquished command to Col. Jeremy Raley, July 13 at Kirtland AFB.

"I am proud to say that over two years ago at the standup of the Space Force, AFRL made a momentous decision to become one lab supporting two services, the U.S. Air Force and the U.S. Space Force," Pringle said.

"Jeremy has big shoes to fill, but let me assure you, Space Vehicles team, that you are lucky," Pringle said. "Col. Raley's credentials in science and technology are long-standing, attaining a doctorate early in his career and applying that knowledge as a bench-level scientist. His assignments have been diverse, spanning research and development and acquisition, and an operational deployment where he was embedded with warfighters, giving him the opportunity to see how our systems and technology work in the field."

Pringle continued by saying that Raley is known for action, performance and getting to the "finish line," while excelling as a phenomenal negotiator. Raley joins AFRL from his position as Director of the Strategic Capabilities Group within the Space Rapid Capabilities Office.

"I have been blessed to be put in this position, and I want to begin by thanking God, my wife, three sons and daughter, who have always been willing to go on the next move and for being supportive throughout this journey, and my thanks to General Pringle for giving me this opportunity," Raley said.

Raley expressed his leadership philosophy of empowering his people and developing a level of trust where his staff is comfortable in bringing him good and bad news.

"It's important that we are good stewards of the taxpayers' money, and show how we are wisely executing those funds and delivering on our promises," he said. "I want us to be willing to take risks and advance our space technology and programs for the best advantage to the nation."

"We have a unique opportunity, Raley continued, to show how space helps those in the terrestrial domain, those on the ground. I have a special interest in this as my oldest son is a Marine Corps lance corporal sitting here in uniform today. I look forward to helping all of our multi-domain warfighters."

U.S. Air Force photo by Staff Sgt. Miranda Loera

AFIT alum Col. Jeremy A. Raley (Ph.D. Electrical Engineering, 2005 and M.S. Electrical Engineering, 2002) assumes command of the AFRL Phillips Research Site as AFRL commander Maj. Gen. Heather Pringle passes him the unit guidon at a change of command ceremony.

CALENDAR EVENTS

SEPTEMBER 2022

AFIT Graduate School Summer Quarter Classes End
02 Sep 2022 I AFIT Campus, WPAFB, OH

AFIT Graduate School New Faculty Orientation Begins
07 Sep 2022 I Virtual Orientation

AFIT Graduate School Summer Graduation Ceremony
15 Sep 2022 I AFIT Campus, WPAFB, OH

AFIT Inaugural Fall Celebration
26-30 Sep 2022 I AFIT Campus, WPAFB, OH

OCTOBER 2022

AFIT Graduate School Fall Quarter Classes Begin
04 Oct 2022 I AFIT Campus, WPAFB, OH

AFIT Distinguished Alumni Awards Ceremony Sponsored by the AFIT Foundation
20 Oct 2022 I AFIT Campus, WPAFB, OH

NOVEMBER 2022

AFIT Graduate School Winter Quarter Registration Opens
08 Nov 2022 I AFIT Campus, WPAFB, OH

DECEMBER 2022

AFIT Graduate School Fall Quarter Classes End
10 Dec 2022 I AFIT Campus, WPAFB, OH

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