AFIT®

Air Force Institute of Technology

GRADUATE SCHOOL OF ENGINEERING AND MANAGEMENT

2018 ANNUAL REPORT

TABLE OF CONTENTS

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A MESSAGE FROM THE DEAN

Welcome to the 2018 Annual Report of the Graduate School of Engineering and Management at the Air Force Institute of Technology. Exciting things continue to happen in our teaching, research, service, and Air Force consultation missions. We continue to thrive on the leading edge of defense-focused research to maintain the global technological superiority of the US Air Force.

I am delighted to draw your attention to the special coverage of AFIT's new Nuclear Research Center in this annual report. The coverage highlights how AFIT has taken a leading role in leveraging diverse education and research to support US Air Force missions at home and abroad.

As an advanced STEM educational institution, AFIT is playing a major role in the advancement of teaching and research in several areas of science and engineering. In recent months, I have become more and more enthused by the global spread and impacts being brought about by the National Academy of Engineering's (NAE) 14 Grand Challenges for Engineering. Many of the challenges align with the critical areas in which AFIT is making contributions from a warfighter perspective that ultimately impacts general STEM applications through structural tech transfer strategies. For your quick reference, the 14 challenges are listed in the sidebar on this page.

The rapidly growing displays on our Patents Display Wall attest to our diverse technical contributions that fit the themes espoused by the grand challenges.

Through this annual report, please join us on our journey of excellence in meeting the needs of the warfighter as well as the needs of society at large. We look forward to your continuing engagement and advocacy for the academic and research programs in the Graduate School of Engineering and Management at the Air Force Institute of Technology.

The impressive Patents Display Wall at the Air Force Institute of Technology outside the Office of the Dean, Graduate School of Engineering and Management.

With the best AFIT regards to all,

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

NAE'S 14 Grand Challenges for Engineering

1. Make solar energy economical
2. Provide energy from fusion
3. Develop carbon sequestration methods
4. Manage the nitrogen cycle
5. Provide access to clean water
6. Restore and improve urban infrastructure
7. Advance health informatics
8. Engineer better medicines
9. Reverse-engineer the brain
10. Prevent nuclear terror
11. Secure cyberspace
12. Enhance virtual reality
13. Advance personalized learning
14. Engineer the tools of scientific discovery

AFIT CELEBRATES 100th YEAR

In 2019, AFIT will celebrate its 100th Anniversary with the theme "**A Century of Education Excellence: Inspiration to Innovation.**"

In honor of that milestone, this annual report provides a look through AFIT's history. In addition, we are planning several events to highlight the impact our faculty, staff, students and alumni made over the last century and explore their current efforts to build and sustain the Joint Force's unmatched twenty-first century military advantages across the globe.

We hope you will consider joining us at the centennial events as we celebrate AFIT and the impact it has had on aerospace and airpower education over the last one hundred years!

If you are an AFIT alumnus, have an AFIT story to share or photos from your time at AFIT as a student, faculty or staff member, please send them to us by visiting **www.AFIT.edu/Centennial/**.

SAVE THE DATE

Centennial Day

7 November 2019

Join us for a day of campus and lab tours, faculty and alumni forums, poster session, formal dedication of a time capsule, and a special Centennial Awards Banquet.

If you are interested in participating in the alumni forums and/or the poster session, please contact Ms. Katie Scott at 937-255-3636 x4393 or email her at **kathleen.scott@afit.edu.**

Above: Dr. John Raquet, Professor of Electrical Engineering and Director of the Autonomy and Navigation Technology (ANT) Center, talks with USAF Chief Scientist Dr. Richard Joseph about his center's research focus areas.

Right: AF Chief Scientist Dr. Richard Joseph gives the keynote address at the AFIT Centennial Symposium on 5 March 2019. (Photos by Kathleen Scott)

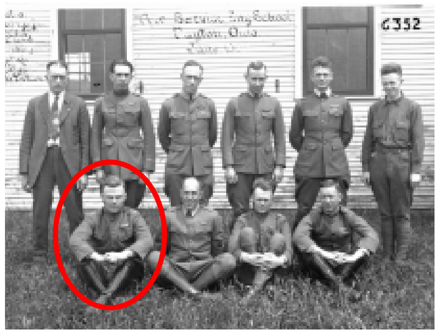
1910's
Air School of Application

10 Nov 1919
Col Thurman Bane receives authorization to begin instruction at the Air School of Application.

His aim was to "give proper technical training…so that Commanding Officers of flying fields will understand thoroughly technical maintenance of airplanes and motors, machine shop installation, shop management and cost accounting, and the operation of machine tools, power plant installation and operation, electricity, metallurgy, lab testing of fuels, gasoline…and elementary aerodynamics"

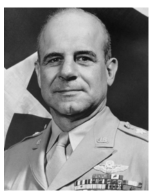
There was no intention of making aeronautical engineers of the students.

1920's
Air Service Engineering School



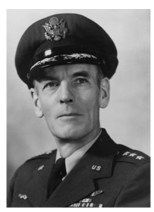
4 Jun 1920
The Air Services Engineering School graduates its 1st class. Lt Edwin Aldrin, father of Col Edwin "Buzz" Aldrin Jr., is a member of the graduating class; stays on as Assistant Commandant and the only military instructor.

1921
General George C. Kenney, a Captain at the time, is a graduate of the 2nd class.



1923
General Jimmy Doolittle, a Lieutenant at the time, is a graduate of the 4th class.

1925
Lt Gen Hubert Harmon, the "Father of the U.S. Air Force Academy", is a graduate of the 6th class.



1930's
Air Service Engineering School

The School is comprised of four departments: fabrication, materials and structures, testing, and design.

1933
Brig Gen Robert F. Travis, then a Lieutenant, graduated; killed in a B-29 crash 15 minutes after takeoff on 5 Aug 1950; Fairfield-Suisun AFB was officially renamed Travis AFB in his honor.

1935
Lt Gen Laurence C. Craigie, then a Lieutenant, graduated. He was the first pilot of the Armed Forces to fly a jet-propelled plane when he piloted the XP-59 on its initial flight at Muroc Dry Lake, CA.

Spring 1939
Col Pearl H. Robey, a 1936 alum, co-piloted the YB-17A equipped with superchargers reaching 311 mph of ground speed at an altitude of 25,000, which was 100 miles faster than any bomber had ever flown before – faster, also, than any fighter plane had ever flown at that altitude.

March 1939
By order of the Secretary of War, new courses were suspended until March 1944.

1940's

Army Air Forces Engineering School

Army Air Forces Institute of Technology

Air Force Institute of Technology

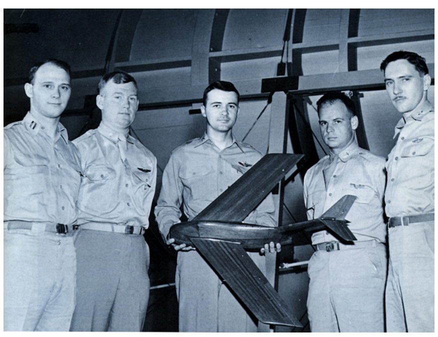
18 Apr 1942
Lt Col Jimmy Doolittle, a 1923 alum, planned and led the Doolittle Raid on Japan; also in the Raid were Lt Col Frank A. Kappeler and Lt Col Harry C. McCool who would each earn their B.S. in Industrial Administration in 1949.

1945


Orville Wright was an honored guest at the graduation ceremony.

Jul 1947
Formally received the mission of conducting "educational courses primarily in the field of engineering sciences and industrial administration."

1948
Most new students already had undergraduate degrees—began a period of planning to raise AFIT to a graduate school.



1950's

USAF Institute of Technology

Institute of Technology, USAF

Air Force Institute of Technology

31 Aug 1954
President Eisenhower signed Senate Bill 3712 allowing AFIT to grant degrees.

1957


Lt Col George E. Hardy, a Tuskegee Airman, earned a B.S. in Electrical Engineering (and in 1964, an M.S. in Systems Engineering); during World War II, he flew 21 escort and strafing missions in North American P-51C and P-51D Mustangs.

1959
Lt Col Mary Strong is the first female AFIT graduate of the resident college with an MBA in Applied Comptrollership.

9 Apr 1959
NASA announced the names of the Mercury Seven: the first Americans to attempt space flight—the group included 1956 alumni Gus Grissom and Gordon Cooper.

1960's

Institute of Technology

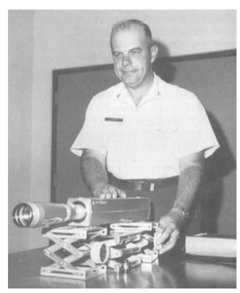
Air Force Institute of Technology

Apr 1960
The School of Engineering received accreditation through the North Central Association.

October 1963
NASA announced the next 14 astronauts including Capt William A. Anders (M.S. Nuclear Engineering, 1962) and Capt Donn F. Eisele (M.S. Astronautics, 1960).

28 Aug 1964
Dedication of the new School of Engineering, building 640.

5 Apr 1965
AFIT's Nuclear Engineering Test Facility, the AF's only nuclear reactor, achieved its first nuclear chain reaction.

1969


Maj Gen Donald L. Lamberson, considered the father of lasers in the Air Force, earned a PhD in Aerospace Engineering in addition to his M.S. in Nuclear Engineering from 1961.

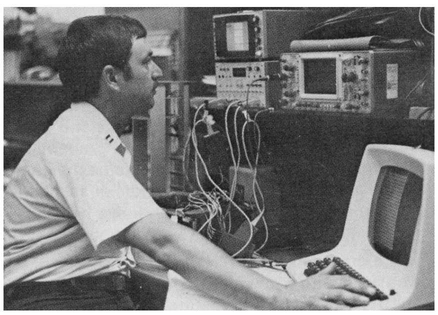
1970's

Air Force Institute of Technology

Era of austerity and transition from war to peacetime.

12 Jun 1970
AFIT's nuclear reactor operated for the last time; now permanently entombed in reinforced concrete.

Fall 1970
Dr. Charles Bridgeman of the Physics Department, delivered AFIT's first distance learning course to students in Albuquerque, NM; he recorded his presentation on video tape, sent it to Albuquerque for replay while he watched a duplicate tape and spoke to the students over the telephone.



1972
The engineering science doctoral program received accreditation.

Late 1970's
First women on AFIT faculty included an instructor in the Civil Engineering School and an assistant professor of humanities in the School of Engineering.

1980's

Air Force Institute of Technology

AFIT developed programs in advanced composites, electro-optics, information processing, laser technology, low observables, radiation hardening, signal processing, and space structures.

1983
Col Guion "Guy" S. Bluford Jr. (Ph.D. Aerospace Engineering, 1978 and M.S. Aerospace Engineering, 1974, with distinction), was the first African American in space.

1985
AFIT implements personnel procedure for civilian faculty based on the traditional four academic ranks (Instructor, Associate, Assistant, and Professor).

1987
General Robert T. Herres (M.S. Electrical Engineering, 1960) became the vice chairman of the Joint Chiefs of Staff.

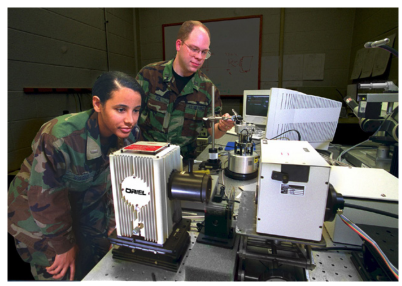
1989
Construction is completed on building 642, Kenney Hall.

1990's

Air Force Institute of Technology

1994
The engineering science doctoral program (the only PhD offered at AFIT at the time) reached its 25th year of awarding the PhD degree.

Mid-1990's
Began teaching courses in computer networks focused on networking theory and technologies, and information operations focused on vulnerabilities and threats associated with the use of these networks.



1 Oct 1999
The Graduate School of Engineering and the Graduate School of Logistics and Acquisition were combined to create the Graduate School of Engineering and Management.

2000's

Air Force Institute of Technology

2000
AFIT established its first research center, the Center for Directed Energy.

2001
Building 644 added 28,810 feet of laboratory space.

2002
Under the initiative of the Secretary of the AF, Dr. James Roche, the first group of enlisted students enrolled in the graduate school.

2005
Mr. Michael W. Wynne (M.S. Electrical Engineering, 1970) became the 21st Secretary of the Air Force.

2006 - 2009
Brig Gen Paula Thornhill served as AFIT's first female commandant.

2010's

Air Force Institute of Technology

2010
External funding of AFIT's research program exceeds $20M/yr, with the diversification of sponsors across the Department of Defense. AFIT research centers include the Advanced Navigation Technology Center, Center for Cyberspace Research, Center for Directed Energy, Center for Operational Analysis, Center for Space Research and Assurance, and Center for Technical Intelligence Studies and Research. Externally designated centers include the Air Force Cyberspace Technical Center of Excellence and the Scientific Test and Analysis Techniques Test & Evaluation Center of Excellence.

Feb 2011
Col Steven W. Lindsey (M.S. Aeronautical Engineering, 1990) commanded the final flight of Space Shuttle Discovery.

2012
Dr. Todd Stewart becomes AFIT's first civilian director and chancellor.

Today

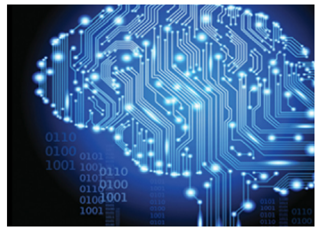
Air Force Institute of Technology

2019
Today, the Graduate School offers 24 research-based, STEM master's degree programs, 14 PhD programs, and 8 graduate certificate programs. It maintains a typical enrollment of over 750 in-residence students and about 120 students in various non-resident programs.

The school provides its students with several significant advantages, including a more personalized educational experience with a student-to-faculty ratio of 5:1 in master's degree programs; academic programs with a defense-related focus; and research on high-priority defense problems.

2020's and Beyond

Air Force Institute of Technology



AFIT is poised to continue to meet the Air Force's and DoD's needs over the next 100 years through defense-focused, research-based graduate education. AFIT continues to grow our research activities in areas such as Artificial Intelligence, Data Analytics, Cyber and Hypersonics; while diversifying our education delivery methods to include graduate certificate programs and courses offered by distance learning.

AFIT looks forward to the opportunity to build upon our previous strategic initiatives to better serve the Air Force's STEM workforce development and research needs consistent with the National Defense Strategy. To this end, AFIT continues to develop research centers, such as the new Nuclear Event Analysis and Testing (NEAT) Center of Specialized Research (CSR).

AFIT's Research Centers

The Autonomy and Navigation Center (ANT), established in 2005, specializes in military PNT. For more information contact Dr. John Raquet, Director at: 937-255-3636 x4671.

The Center for Cyber Research (CCR), established in 2002, conducts cyber security and operations research at the Master's and PhD levels. For more information contact: Dr. Scott Graham, Director, at: 937-255-3636 x4581.

The Center for Directed Energy (CDE), established in 2000, to conduct research which would influence the evolution of directed energy. For more information contact Dr. Steve Fiorino, Director at: 937-255-3636 x4602.

The Center for Operational Analysis (COA), is a premier research facility which directly supports Department of Defense strategic objectives. For more information, contact Dr. Darryl Ahner, Director at: 937-255-3636 x4708.

The Center for Space Research and Assurance (CSRA), established in 2012, to discover and demonstrate cutting-edge science & technologies to address current and future defense and national security needs in the space domain. For more information, contact Col Timothy Albrecht, Director at: 937-255-3636 x4753.

The Center for Technical Intelligence Studies and Research (CTISR), established in 2001, brings together cleared faculty across academic departments to solve difficult, multi-disciplinary technical intelligence problems. For more information, contact Dr. Kevin Gross, Director at: 937-255-3636 x4558.

The Scientific Test & Analysis Techniques Test and Evaluation Center of Excellence (STAT T&E COE), established in 2012, to provide independent advice and assistance to major acquisition programs to increase the understanding and effective use of scientific test and analysis techniques in the Department of Defense's acquisition community. For more information, contact Dr. Darryl Ahner, Director at: 937-255-3636 x4708.

New Center to Support Renewed Efforts in Nuclear Research

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The effects of nuclear weapons have far-reaching implications to strategic missions, which drive various research and development interests spanning multiple academic disciplines. In addition to the traditional disciplines of nuclear physics and nuclear engineering, these varied disciplines include: material science, meteorology, biology, chemistry, electrical engineering, political science and systems engineering. Technical expertise that is "nuclear aware" in these areas resides in a relatively small population of human capital within the Nation and our strategic allies.

The Air Force Institute of Technology (AFIT) currently possesses the most capable faculty and student base to serve as the focal point to provide technical expertise for classified and unclassified interdisciplinary research efforts for national defense, academia and industry. AFIT has a long history of supporting the Nation's nuclear research and development efforts. During the Cold War, AFIT was host to the Nuclear Engineering Center (NEC), centered at the (now decommissioned) research reactor.

> "The nuclear weapons infrastructure depends on a highly-skilled, world-class workforce from a broad array of disciplines, including engineering, physical sciences, mathematics, and computer science. Maintaining the necessary critical skills and retaining personnel with the needed expertise requires sufficient opportunities to exercise those skills."
>
> — *Nuclear Posture Review, 2018*

Nuclear Engineering Center (NEC) centered at the now decommissioned research reactor.

The NEC was decommissioned as national priorities shifted. However, a renewed interest exists within the Air Force and the national nuclear enterprise to form a multi-disciplinary focal point for the development of nuclear knowledge and to conduct defense-focused nuclear research.

The Nuclear Event Analysis and Testing (NEAT) Center of Specialized Research (CSR) is proposed to address these requirements and coordinate nuclear knowledge development and research activities throughout the Air Force and the nuclear enterprise. The primary functions of the center will be to develop career professionals in support of the US nuclear modernization and sustainment mission, provide research consultation to ensure the USAF remains an informed customer in nuclear diagnostics and weapon related topics, provide educational support to enhance nuclear knowledge across the board, and provide a publication/interaction space to share important ideas and concepts for the nuclear enterprise.

Whatever your requirement, AFIT is ***"ready to join with you in solving your nuclear problems through focused education and research efforts."***

–NEC Brochure, 1963 (unpublished)

Who Done It? Attributing the Origin of a Surprise Nuclear Strike

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During the Cold War, the possible source of a nuclear strike on US soil was clear. Few nations possessed nuclear weapons and had the ability to deliver them to the US. However, this has changed dramatically in the past 30 years. Many new, and arguably less stable, nations have joined the nuclear club. Additionally, the proliferation of nuclear technologies and advanced manufacturing techniques has lowered the nuclear threshold at a time when terrorist organizations have demonstrated unprecedented organization and access to resources. Today, the source of a nuclear detonation would be far less clear.

Nuclear forensics aims to answer this question through using the characteristic "fingerprints" left by nuclear weapons that can help identify both the origin and the design. One of these fingerprints is the bomb debris. However, since the cessation of nuclear weapons testing, the US cannot generate realistic surrogate debris for training and research. AFIT is engaged at all stages of addressing this critical challenge.

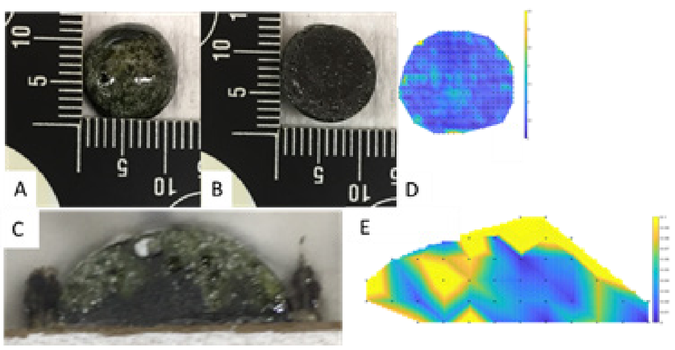

Fig. 1. Top (A), bottom (B), and center (C) cross sections of a synthetic surrogate debris sample and uranium elemental maps (D, and E) produced via LIBS

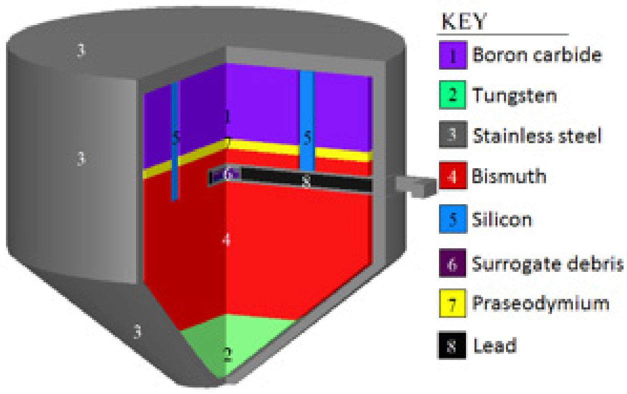

Fig. 2. ETA developed for NIF to replicate nuclear weapon debris.

AFIT, University of Tennessee, and Oak Ridge National Laboratory have developed surrogate debris formulations representative of the glass fallout that would be retrieved following a nuclear detonation. LTC Michael Shattan has become a leading researcher in developing field portable debris analysis techniques for these samples to obtain rapid forensics information. Figure 1 shows the use of a novel, portable Laser Isotope Breakdown Spectroscopy (LIBS) system to analyze one of these samples.

However, samples created to date do not have the activation and fission products critical for forensics purposes. Capt Nicholas Quartemont is using the National Ignition Facility (NIF) to solve this problem. Figure 2 shows the energy tuning assembly (ETA) that Capt Quartemont will use at NIF to replicate a nuclear weapon neutron environment and generate surrogate nuclear weapon debris.

Future collaborations with DOE national laboratories will incorporate the surrogate debris generated by Capt Quartemont to enable the development of improved nuclear forensics techniques.

AFIT Collaborates to Fill Gap in Validation of Nuclear Weapon Effects Models

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US nuclear testing was halted in 1992 by a presidential moratorium. Consequently, modeling and simulation of nuclear detonations has become the go-to mechanism for predicting the outcomes of these events. This ability is vital to the security of the United States for a variety of reasons, ranging from stockpile stewardship to consequence management in the event of a nuclear attack. Validation of modern models and simulations is a priority mission throughout the national nuclear enterprise. This validation is a critical step in the model development and uncertainty reduction process, but it is difficult due to model complexity and the absence of modern nuclear testing data.

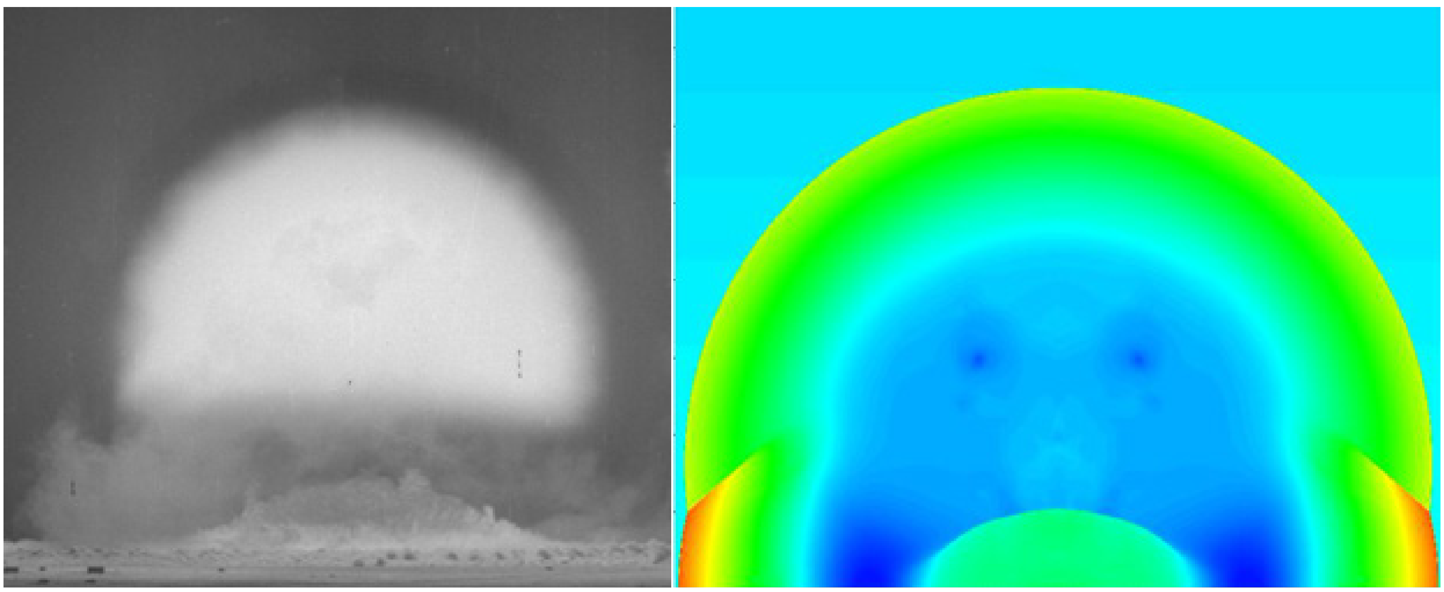
During the last several years AFIT, in collaboration with Lawrence Livermore National Laboratory and the Defense Threat Reduction Agency, has been working to fill this gap in validation capability by leveraging archived scientific nuclear test films. Digitizing and analyzing these films has allowed validation data to be extracted using modern computational techniques.

A recent example of this work is currently being conducted by Lt Will Johnston. His work is focused on validating the outputs of two widely used weapons codes: SHAMRC, a high-fidelity 2D radiation dominated hydrodynamics code, and RECIPE, a fast running weapons effects code used widely by operational nuclear organizations, against a fallout-free height-of-burst nuclear detonation, specifically the test known as Upshot-Knothole Grable from 1953.

The work thus far has demonstrated the validity of the nuclear shockwave characteristic outputs of these weapon codes and similar techniques will be applied to the nuclear spectral outputs in the near future.

Additionally, these techniques will be applied to other, more challenging nuclear weapon emplacement scenarios in an attempt to validate the codes against more complex targets. Once complete, these validation results will be provided to model development organizations throughout the national nuclear enterprise.

"The work thus far has demonstrated the validity of the nuclear shockwave characteristic outputs of these weapon codes and similar techniques will be applied to the nuclear spectral outputs in the near future."



Direct comparison of the digitized historical nuclear film (left) to the pressure profile produced by SHAMRC (right) of shot Grable from the Test Series Upshot-Knothole.

Radiation Source Direction Identification and Imaging Using a Portable Rotating Scatter Mask System

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Locating radiation sources, whether lost, distributed over a large area due to an accident, or intentionally hidden for trafficking purposes, using standard detection technologies is a time-intensive process that increases exposure risk to personnel. To address this challenge, AFIT students Lt Jack Fitzgerald, Maj Chris Charles, Julie Logan, Lt Robert Olesen, and Capt Zachary Condon designed, built, and tested a rotating scatter mask (RSM), shown in Figure 1, that could be used to determine the direction of radiation sources. The RSM design has significant size, field-of-view, and energy-range advantages over comparable systems. However, the original system was still fairly large (42 x 13 x 24 in.), and weighed approximately 50 lbs (27 lbs for the mask alone).

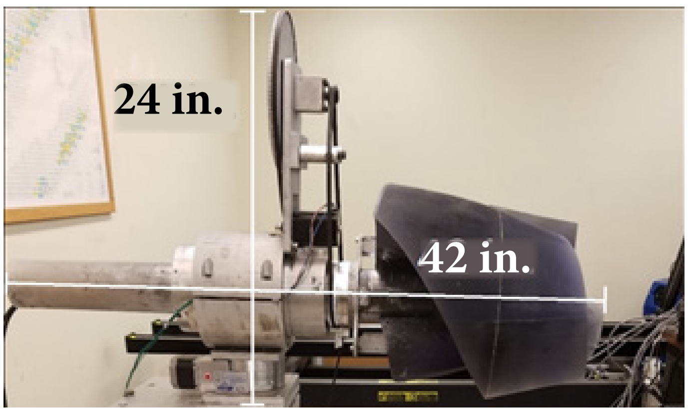

Fig. 1. Previous RSM with support (left half), rotating equipment (center) and mask (right).

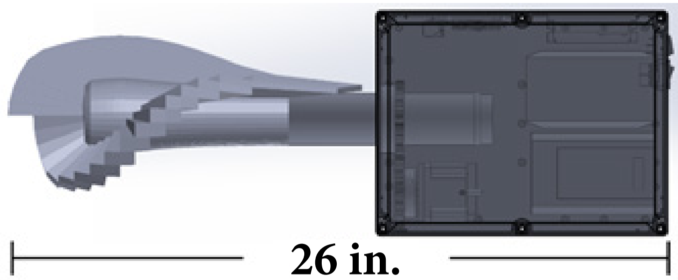

Fig. 2. New RSM system offering improved portability and gamma source direction identification.

Since many radiation search applications involve mobility, designing a portable detection system is critical to making the RSM an operational success. Valarie Martin, a summer intern, tackled the challenge of developing a more portable system. The system she developed is shown in Figure 2, incorporates a new mask design developed by Lt Olesen. The new RSM system weighs approximately 16 lbs (1.5 lbs for the new mask) and contains all of the equipment inside a 26 x 11 x 5 inch volume. The result is a system that can be carried into the field or attached to an unmanned aerial vehicle and flown over an area of interest. Additionally, the simpler mask design improves the speed and accuracy of the system in determining the direction of a radiation source.

Ongoing research by Lt Bryan Egner focuses on adapting the RSM to function as a dual neutron-gamma detection system. Since the mask's performance is dependent on its geometry and material choice, mask optimization efforts are focused on increasing the detection efficiency and differentiability. Lt Olesen is using the increase in differentiability to make the RSM function as a full radiation imaging system to map multiple or distributed radiation sources.

HPC Initiatives in Support of Nuclear Research and Education

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The graduate nuclear engineering program has been working in collaboration with the Air Force Research Laboratory's DoD Supercomputing Resource Center (DSRC) to commission a new high performance computing (HPC) cluster dedicated to nuclear research and education at AFIT. This new Linux cluster is named after the late Dr. Charles Bridgman, one of the founding fathers of the AFIT nuclear education program, and is dedicated to the principles of excellence in research and education that he promoted. Initial commissioning of the Bridgman Cluster was achieved during the summer of 2018. In its initial modest configuration, the cluster consists of 160 CPUs operating at 2.1 GHz. Bridgman was built upon an expandable platform, allowing for future growth, and is intended to provide a "sandbox" where nuclear engineering students and faculty can develop parallelized software to solve cutting-edge problems in the fields of radiation transport, nuclear materials detection, detector optimization and nuclear treaty monitoring.

The Nuclear Engineering faculty have updated the program's curriculum to incorporate the Bridgman Cluster in solving computational nuclear engineering problems. The course, Computational Methods for Neutral Particle Transport, NENG685, taught by Capt James Bevins, includes a final project where students tackle an open-ended computational research topic. Nuclear Fuel Cycles, NENG681, taught by Dr. Larry Burggraf, challenges teams to develop nuclear and thermodynamic simulations in support of radioisotope propulsion. Advanced Nuclear Forensics, NENG880, taught by Dr. Abigail Bickley, requires students to develop nuclear forensics simulation tools to determine the origin of nuclear forensic signatures.

Two examples of computational tools developed by students include a chronometry calculator for radioactive sample age dating and a reactor burn-up calculator to determine the type of reactor that produced a uranium or plutonium sample based on isotopic assay. These projects push the students beyond their desktop computers and into the world of high performance computing so they are well poised to take advantage of the vast DoD computing resources for their research and future careers.

During the September 2018 short quarter, MS and PhD students entering the nuclear engineering program were provided an intensive 3-day training class on how to use the SCALE modeling and simulation suite to address fundamental problems of radiation transport, reactor modeling and fuel decay. Instructors for the course were Dr. Will Wieselquist (SCALE Director) and Dr. Mathew Jessee (SCALE Developer) of Oak Ridge National Laboratory.
(Photo taken by Dr. A.A. Bickley.)

Using High Performance Computing, Data Mining, and Visualization Techniques to Optimize Geosynchronous Earth Orbit Space Situational Awareness

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With space now identified as a warfighing domain, there is interest in enabling US space supremacy by use of modeling, simulation, and analysis. An impediment to that effort, however, is that space scenarios are computationally complex and real-world sized scenarios are very large. Typically, the desired output is not a single answer, but rather a range of answers whether for sensitivity analysis or trade studies, or perhaps a pareto front of near-optimal solutions resulting from multi-objective optimization.

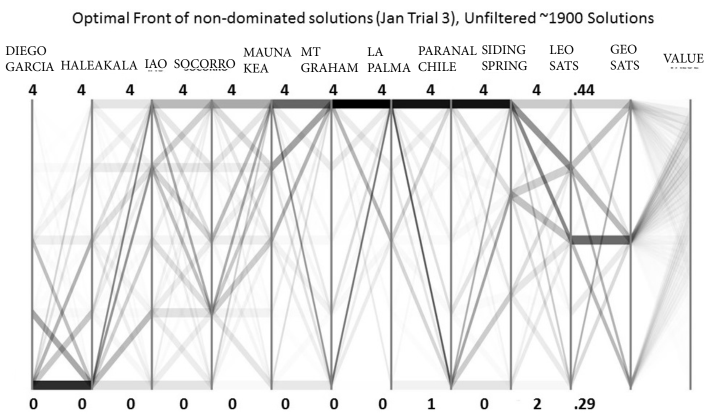

Fig. 1. An example of Paraview's visualization. Here the different levels of individual predictors, with a measure for how frequently those levels are used is displayed.

The answer to this impediment for the Center for Space Research and Assurance (CSRA) was to work with Analytical Graphics Incorporated and the Air Force Research Laboratory Defense Supercomputing Resource Center to be able to install and run a UNIX based version of Systems Tool Kit (STK) on a high performance computer (HPC), and in a parallelized fashion. Parallelization was the key needed attribute: the UNIX version of STK is not currently parallelizable, meaning running a single problem on an HPC offers little speed advantage over what can be done on a standard desktop machine. But by pleasingly parallelizing STK, hundreds, even thousands of instances of STK can be run simultaneously, dramatically reducing the amount of time required for data generation. However, running so many instances of STK can create terabytes of data. Fortunately, the DSRC connected CSRA students with their visualization team. The team introduced the visualization tool Paraview (shown in Figure 1), which, combined with data mining was utilized by the students to take the raw data and plot it so as to provide actionable information, not just data.

Today, CSRA students are using the HPC Thunder (shown in Figure 2), which at the time of its installation, was about the 25th fastest machine in the world, and have done research that without the machine, STK, or Paraview would have otherwise been impossible to perform otherwise.

Fig. 2. The DSRC HPC Thunder.

Rigorous Design of Experiments for the Littoral Combat Ship

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The Littoral Combat Ship (LCS) program partnered with the Scientific Test and Analysis Techniques Center of Excellence (STAT COE) to review test designs to identify possible efficiencies that could be gained for their Anti-Submarine Warfare (ASW) and Surface Warfare (SUW) mission packages. Several designs were already in place and were presented to the STAT COE. Through discussion with the ASW team, subject matter experts were able to narrow their focus to the most important factors that had not been previously studied. This allowed the STAT COE to develop two potential courses of actions to maintain effectiveness while increasing the efficiency of test resources.

In SUW, the STAT COE facilitated a discussion that resulted in an increased emphasis on TRACKEX. Additionally, FIREX was adjusted for a more robust and encompassing test with an option for validation on the second variant. This design more effectively addresses the questions required for effective program and acquisition leadership decision making.

Littoral Combat Ship
Photo source: https://www.navy.mil/view_image.asp?id=265126

With the help of subject matter experts and good discussion, the STAT COE was able to provide efficient and effective alternative designs. The estimated cost avoidance to date for this effort is nearly $30M and the tests are still producing all of the decision quality knowledge required.

For more information about the STAT COE, please contact Dr. Darryl Ahner, STAT COE Director, at 937-255-3636 x4708 or darryl.ahner@afit.edu

Applying Scientific Test and Analysis Techniques to the F-35

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Following a series of in-flight physiological episodes (PEs) in 2017, the F-35 Joint Program Office (JPO), organized an Action Team (AT) composed of JPO engineers, operators, subject matter experts (SMEs), contractor engineers, and program personnel. Immediate issues focused on performance of the F-35 On-Board Oxygen Generating System (OBOGS), the fidelity of oxygen levels recorded by aircraft during incidents, and the answer to the question–does the F-35 Life Support System (LSS) generate sufficient oxygen to prevent onset of hypoxia?

The engineering response concluded a disciplined application of Scientific Test and Analysis Techniques (STAT) would provide the most defensible data to program decision-makers. The STAT Center of Excellence (COE) designed an initial 17 test sequences. Of these, 12 were conducted on three OBOGS from incident F-35 aircraft and one lab test OBOGS, resulting in 576 successfully executed test points. Test designs evaluated factors' main effects and interactions on responses including oxygen levels, control stability, and mask pressures. In all cases, testing demonstrated high levels of repeatability and statistical robustness, giving a high level of confidence with sufficient evidence to support the following conclusions:

- We can trust oxygen concentrations recorded by F-35 aircraft in-flight
- F-35 in-flight-recorded oxygen concentrations provided reasonable estimates of oxygen concentrations delivered to pilots
- There is no evidence of undetected oxygen concentration disruptions; testing demonstrated the F-35 life support system appropriately detects and reacts to failures, delivering oxygen levels well above minimums required to prevent hypoxia

Pilot testing the OBOGS during pre-flight checks.
Photo source: http://www.flickr.com/photos/usairforce/15390181716/

The evidence compiled strongly supports the hypothesis that PEs reported were likely not a result of OBOGS failing to deliver oxygen at levels required to prevent hypoxia. The F-35 LSS team is using these results to develop a robust understanding of OBOGS concentrator functionality to guide requirements and identify significant system improvements.

"There is no evidence of undetected oxygen concentration disruptions; testing demonstrated the F-35 life support system appropriately detects and reacts to failures, delivering oxygen levels well above minimums required to prevent hypoxia."

Implementing Mission-Based Design of Experiments in Acquisition

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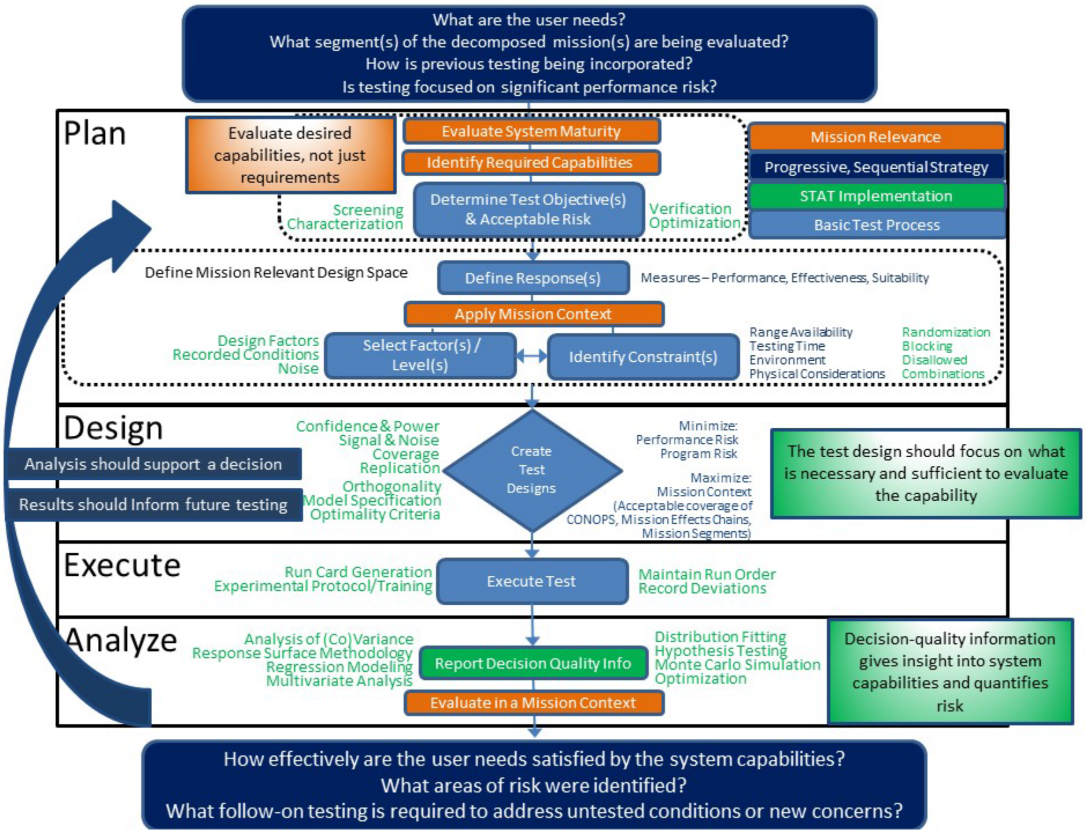
The Scientific Test and Analysis Techniques Center of Excellence (STAT COE) was requested to assist the Reform Management Group (RMG) for Testing, established by the Chief Management Officer (CMO) of the Department of Defense (DoD), to identify potential efficiencies in testing. Specifically, the STAT COE provided three reports to help frame the implementation and optimization of Mission-Based Design of Experiments (MBDOE) within the DoD. MBDOE is the application of mission relevancy in progressive, sequential DOE to inform evaluations throughout the test continuum. MBDOE incorporates the use of a methodology that focuses acquisition testing over the expected range of realistic and relevant combat conditions and threats with subsequent evaluations to ensure testing emulates how the user fights, including the system-of-systems (SoS) required to enable the operational capability to the warfighter. The three key elements of MBDOE are: 1) application of mission relevancy, 2) progressive and sequential nature of DOE testing, and 3) implementation of STAT.

The Baseline Assessment reviewed current policy and guidance to support MBDOE, as well as opportunities and challenges for implementation. It attempts to capture a baseline for the current status of DOE rigor when applied to testing as well as mission-relevance in testing. The Implementation Plan outlined an approach that included rationale for updating policy and guidance to focus on MBDOE, its cultural development, and how to promulgate its influence throughout the DoD. This plan established key ideas related to workforce recruiting needs, development of training, and academic partnerships to implement the combination of STAT, systems engineering, operations, and program management.



The Mission-Based Tiered DOE Methodology, graphically depicted in Figure 1, suggested guidelines for developing test strategies and discusses how to implement mission relevance, a progressive, sequential strategy, and STAT into the test and evaluation process.

For more information on the STAT COE, please contact the director, Dr. Darryl K. Ahner, at 937-255-3636 x4708 or darryl.ahner@afit.edu.

Profiling of Atmospheric Turbulence Using Two Beacons and a Hartmann Turbulence Sensor

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Dr. Jack E. McCrae, Dr. Christopher Rice, Dr. Steve Fiorino

The Hartmann Turbulence Sensor (HTS) is an optical system, primarily comprising of a 40 cm Meade telescope, a 32 x 32 Shack- Hartmann lenslet array, and a high-speed Phantom camera. The HTS estimates atmospheric turbulence parameters by measuring the local tilts of the aberrated wavefront coming from a laser source and incident at the pupil plane of the telescope. At the Center for Directed Energy, a technique has been developed to measure the distribution of turbulence along an experimental path using the HTS and two laser sources. By measuring the variances of the difference in wavefront tilts due to the two sources sensed by a pair of Hartmann subapertures with varying separations, turbulence information along the path can be extracted. The method relies on deriving a set of turbulence weighting functions, each weighting function dipping to zero at a range where the two sensing paths from the laser beacons to the subapertures intersect, thus canceling out the effect of turbulence at this location on the differential tilt signal. The technique has been applied to experimental data collected over a 500 m almost horizontal path over grass and the profiling results have been compared to a co-located scintillometer.

Figure 1 shows a profile of the refractive index structure constant, or obtained using this method. The red trace corresponds to estimated values assuming is constant along the path and is equal to the scintillometer measured value.

The generated profiles are in agreement with the scintillometer measurements. The undulations seen in the plots are due to noise in measurement and estimation. The slight drop in the middle of the path and a slow upward trend later is possibly due to the fact that the path was not exactly level. Close to the source end of the path (z >380 m), the present technique fails to profile turbulence. However, an integrated value of for this last section of the path can be obtained. Negative values are sometimes seen, probably when the estimates hit the noise floor. These are seen as gaps in the profile.

A significant advantage of the present method is that it is phase-based, and hence can be applied to long paths through turbulence where the irradiance-based techniques suffer from saturation problems. In the future, experiments will be conducted over slant paths. Successful profiling over slant paths will ultimately help in understanding how turbulence changes with altitude in the lower atmosphere.

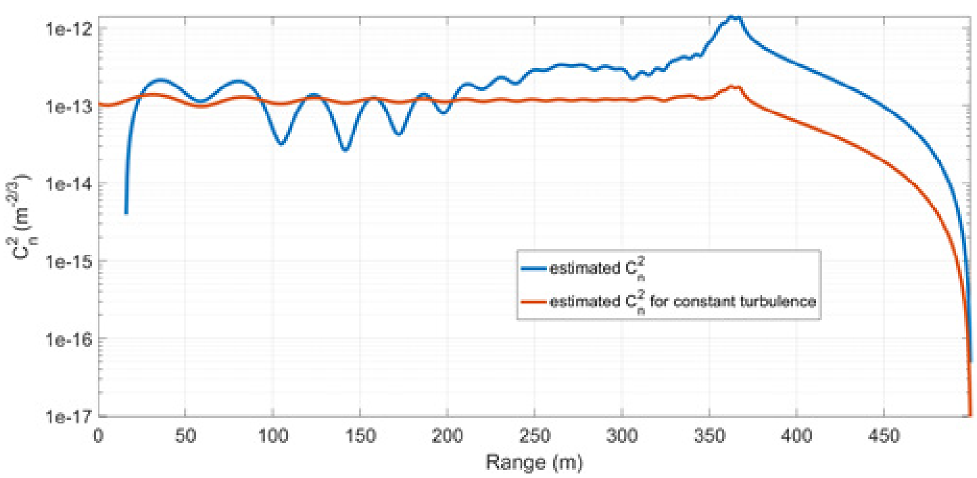

Fig. 1. Profile generated for June 7, 2018 10:20 AM local daylight time (UTC -4 hours). The HTS is at z = 0 and the sources are at z = 500 m.

Total Solar Eclipse Provided Opportunity to Investigate Atmospheric Processes

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Dr. Kevin Keefer, Dr. Lee Burchett, Dr. Jaclyn Schmidt, Dr. Aaron Archibold

The total solar eclipse on August 21, 2017 provided a unique opportunity to observe and investigate atmospheric processes, specifically turbulence and aerosol dynamics, which largely are tied to absorption of solar irradiation by the earth's atmosphere and surface. During the eclipse the sun's radiative regime was reduced (up to 89% where the measurements were taken) equally across all spectral bands for nearly three hours. Thus, the total insolation, whether one's location was in the path of totality or not, varied in a manner quite different than typical cloud obstructions during a normal diurnal solar cycle.

Solar irradiance is a primary driver of near surface turbulence (C_n^2) and depending on the source for the estimated C_n^2, this is exemplified to an extent in the passing cloud events in the solar irradiance plot and modeled C_n^2 plots in Fig. 1 (top two plots) below. Furthermore, the profiles show definite correlation between the ambient ultra-fine aerosol population (measured with a Condensation Particle Counter or CPC) and the onset of the eclipse and obscuration of solar radiation. However, the surface horizontal wind speed (Fig. 1, 3rd plot from top) did not appreciably drop during the eclipse period, thus the significant drop in ultra-fine aerosol total number concentration (Fig. 1, 4th plot from top) during this period was somewhat surprising.

In summary, a study was conducted on aerosol, turbulence, solar irradiance, wind speed, and relative humidity measurements during a near-total eclipse event. The near surface ultra-fine particle counts seemed more closely tied to solar irradiance and near-surface turbulence than to surface wind speed or relative humidity. It is speculated that the ultra-fine scale particle counts are tied directly to the vertical motions associated with the near-surface turbulence and natural and anthropogenic (e.g. automobile exhaust) sources of aerosol particles. It was reported that automobile traffic was significantly reduced during the eclipse as many people stopped to observe the event.

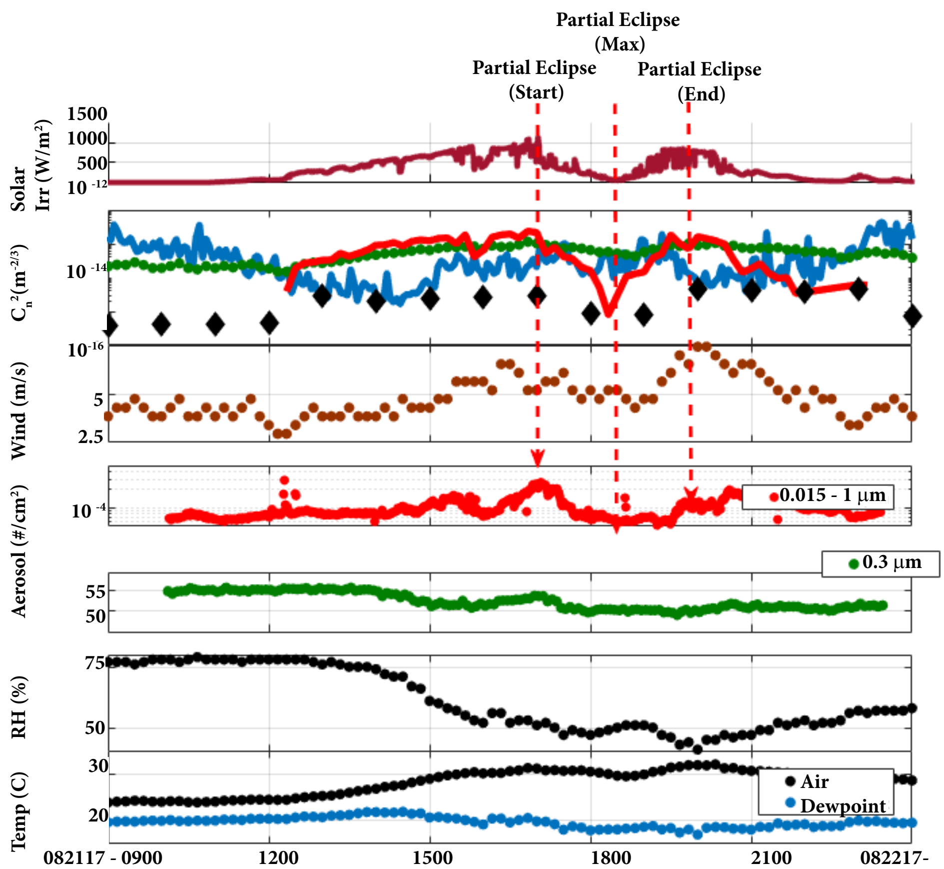

Fig. 1. A comparison of measured solar irradiance (top plot), derived C_n^2 (including the RSD model, Tatarski model, and NEXRAD, Wx Radar GFS - derived C_n^2), measured wind speed, measured aerosol total particle counts, measured large particle counts, relative humidity, temperature and dewpoint on 21 Aug 17 at Wright-Patterson AFB, OH.

Heavy Auto-GCAS: Science of Collision Prevention

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The F-16 Automatic-Ground Collision Avoidance System (Auto-GCAS) has been a resounding success since implementation in Nov 2014 – saving 8 pilots and 7 aircraft from Controlled Flight into Terrain (CFIT). But what about "heavy" aircraft in the Air Force inventory such as C-130, C-17, and B-1?

Urgency exists to implement an Auto-GCAS system on heavy aircraft that perform low-level flying missions and operate in mountainous terrain. Working closely with faculty and cadets from the USAF Academy, the study team found that from 1992 to 2015, the US DoD had 28 C-130 Class A mishaps. Five of these were Auto-GCAS preventable, which would have saved 34 lives, with many more possible if extended to civil aviation.

Research sponsored by AFRL with AFIT/ENY (Dr. Richard Cobb and students) aims to eliminate CFIT for heavy aircraft by creating a new Auto-GCAS algorithm which includes forward climbs with lateral escape maneuvers suitable for the lower climb performance characteristics of heavy aircraft.

Modeling a surrogate LJ-25 aircraft, the new algorithm takes the current aircraft position and state variables (Euler angles, body velocity vectors, and latitude/longitude position) and projects the future aircraft spatial location. For each projected location, five pre-determined escape maneuvers are calculated, namely, level left turn, climbing left, forward climb, climbing right, and level right turn. Next, each escape maneuver path altitude is compared to the Digital Terrain Elevation Data (DTED) altitude. This differential height represents height above terrain (HaT). If HaT is less than zero (plus a buffer), the maneuver path is closed. Before all paths are closed, the algorithm executes the last open path, and continues executing escape maneuvers until the forward climb path is open, handing control back to the pilot.

Current research explores extending the time spans of the existing maneuver path predictions by using an adaptive integration step with refined path selection criteria and higher order accuracy maneuver path predictions. Early simulations in test terrain indicated that simply extending the length of the maneuver path does not prevent collisions with vertical cliff walls, a real concern for

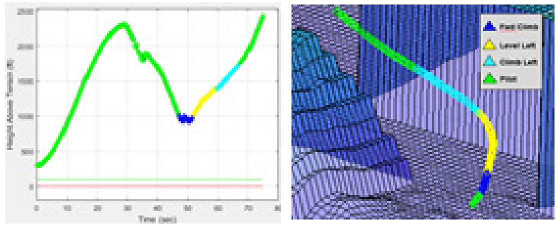

Fig. 1. Height above Terrain (HaT) for a simulated flight towards a cliff wall, successive escape path activation before handing back to pilot

low-level operations. A new approach of changing when the GCAS algorithm returned control back to the pilot from a first-path open to a forward-climb open resulted in successful evasions of cliff walls. Figure 1 shows a sample HaT graph and sequence of escape maneuvers when flying toward a cliff wall.

To validate the work, flight tests (Have ESCAPE and Have MEDUSA) were conducted at the USAF Test Pilot School (TPS) in September 2015 and 2018 (Figure 2) yielding positive results and demonstrating the ability of the algorithm to control the LJ-25 safely against virtual terrain while operating within limits of +2.5g and 12 deg AoA.

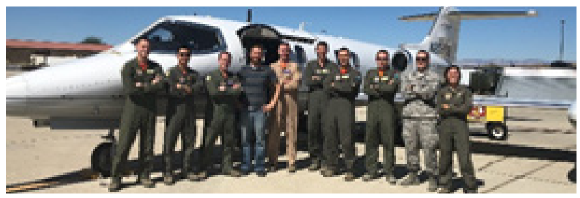

Fig. 2. TPS Flight Test, Have MEDUSA Crew with Calspan LJ-25 test aircraft, Sept 2018. AFIT students Maj Chris Gahanand Capt James Carpenter are developing and testing heavy Auto-GCAS as part of their graduate research.

To further mature the heavy Auto-GCAS design, AFRL and AFIT will conduct a piloted study in December 2018 to evaluate candidate cockpit displays and nuisance criteria using AFRL's Multi-Crew Capsule (MCC) simulator, shown in Figure 3.

The MCC simulates a realistic heavy flight deck with visually moving terrain, integrated Heads-Up-Display and Multi-Function Displays. The results of the September flight tests and the December simulator studies will be presented to the AMC commander to obtain user buy-in and inform future flight tests.

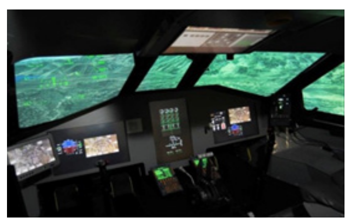

Fig. 3. AFRL Multi-Crew Simulator with virtual terrain

Unique Decision Aid for Free Space Optical Communication Using Worldwide 4D Weather Cubes

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Dr. Jaclyn Schmidt, Dr. Brannon Elmore,
Dr. Kevin Keefer

Terrestrial free space optical (FSO) communications architectures have caught the attention of commercial, civil, and US Government Agencies, including the DoD, as they seek to meet ever-growing demand for increased bandwidth and data rates. This technology is susceptibility to atmospheric effects, especially optical turbulence and interference (extinction) as the beam passes through clouds, fog, aerosols, and precipitation. While atmospheric extinction leads directly to lower signal-to-noise, optical turbulence effects result in beam spreading and random fluctuations in intensity at the communication link's receiver, resulting in signal fade during voice communication and bit errors in data packets. The literature assesses the impact of such effects on FSO communications and seeks to develop decision aids to: a.) predict FSO communications performance using numerical weather prediction (NWP) data; and b.) support network optimization through alternate capabilities such as millimeter wave (MMW)-based communications.

AFIT's Center for Directed Energy (CDE) was co-sponsored by the DoD Directed Energy Joint Transition Office and the DoD High Performance Computing Modernization Program Office's Workforce Development initiative to advance such decision aids. Anchored to AFIT CDE's Laser

Story continued on next page

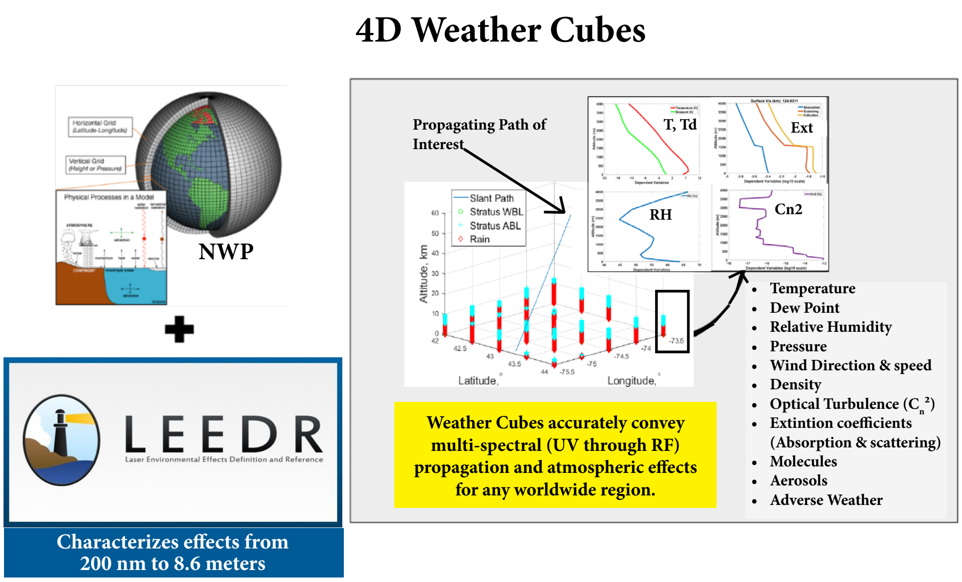

Fig. 1. The features of a 4D Weather Cube: an innovation for weather effects decision aids. A 4D Weather Cube is generated through interrogation and aggregation of the National Oceanic and Atmospheric Administration's Global Forecast System model data using AFIT-CDE's LEEDR tool, a verified and validated atmospheric characterization and radiative transfer code. Besides depicting traditional weather parameters, 4D Weather Cubes can show multispectral profiles of cloud and rain as well as optical effects (e.g. light absorption and scattering).

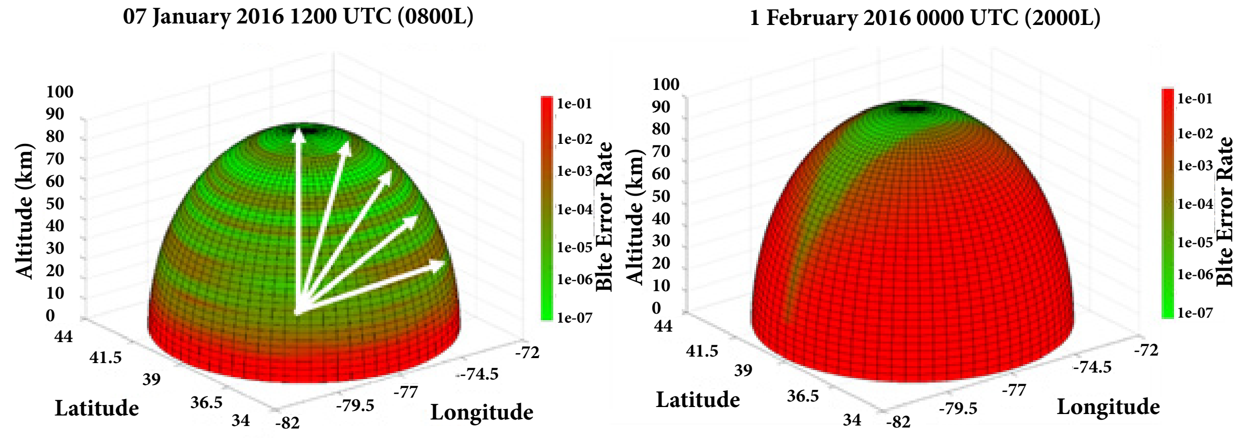

Fig. 2. BER performance domes, originating from 4D Weather Cubes centered on the National Capital Region, displaying BER by azimuth and zenith angles on two days at different times in 2016. The color scale indicates high (red) and low (green) BERs, wherein BERs of 1e-6 and smaller can be treated as acceptable performance. The white arrows depict five representative zenith angles evaluated for 2016 FSO performance. The banding seen in the BER dome on the left is thought to be associated with variations in forecasted optical turbulence strength and cloud layers encountered along the path. The BER dome on the right forecasts poor communications in nearly any direction one might point the uplink, which is likely due to widespread overcast conditions.

Environmental Effects Definition and Reference (LEEDR) model and NWP data, an entire year of Weather Cubes were aggregated and interrogated using AFRL's Thunder High Performance Computer.

Figure 1 demonstrates how Weather Cubes capture spatial and temporal variations in atmospheric conditions over large, gridded regions. AFIT-CDE's High Energy Laser End-to-End Operational Simulation (HELEEOS) code, utilizing Weather Cubes to surrogate the atmosphere along FSO communication uplinks, quantified peak signal intensity at the communication link receiver to enable calculations of bit error rates (BERs), a standard performance metric. Performance results are shown in Figure 2.

This exploratory research demonstrates the utility of Weather Cubes for FSO communications decision aids and extends to BER percentile performance analyses, which aggregated overall performance trends for various uplink orientations over the entire year of weather conditions. One can envision aggregating forecast weather data in the same manner to provide the system operator foresight on best utilization of a mixed FSO and MMW communication architecture. Future research will evaluate performance analyses for a 10-year-period and multiple worldwide locations.

Center for Space Research Assurance: Grissom 6U Bus

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The Center for Space Research and Assurance (CSRA) is developing Grissom, a space-qualified 6U CubeSat bus to support hands-on student education and research. Students will use the Grissom 6U busses in both classroom and thesis work to design, build and test CubeSat missions.

The project is named after Mercury astronaut Virgil "Gus" Grissom, a 1956 AFIT graduate in aeromechanics. It will leverage significant bus component and core flight software development performed at AFIT by CSRA research staff, faculty, and students over the past few years. It will include in-house hardware and software development, bus integration and environmental testing.

According to Colonel Tim Albrecht, CSRA director, "One advantage of our Grissom design is affordability—we can build a Grissom bus for about a third of the cost of a similar COTS (commercial off-the-shelf) CubeSat bus."

Cutting-edge flight software design represents one of Grissom's most innovative features: leveraging state-of-the art software architectures from industry. CSRA is tailoring an open-source CubeSat core flight software from Kubos, a small business startup. The Grissom software will have the ability to upload new flight and payload software and firmware while on-orbit. The modular software design will enable upgrades or modifications to the satellite mission over its lifetime and allow on-orbit experimentation.

The Grissom bus is already featuring in CSRA's plans for on-orbit experiments. The students in the 2018 Space Vehicle Design course sequence used a prototype Grissom, putting it through a sequence of environmental qualification tests.

"We learned a lot and we're in talks with the sponsor to build follow-on flight vehicles for launch within the next few years," said Col Albrecht.

"In addition, we're now on tap to deliver the first spaceflight vehicle based on Grissom by the end of calendar year 2019 for another sponsor."

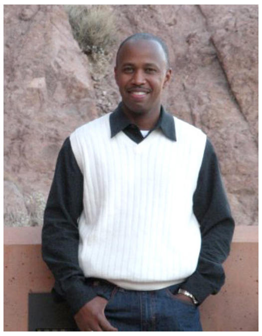
A research assistant from the Center for Space Research and Assurance assembles a Grissom satellite chassis in the CSRA's clean room. CSRA students learn Space Vehicle Design by integrating the chassis with a research payload, subjecting it to vibration and thermal-vacuum tests to predict whether it will survive the harsh environment during launch and on orbit. (Air Force photo)

For more information about the CSRA, please contact Col Timothy Albrecht, CSRA Director, at 937-255-3636 x4679 or timothy.albrecht@afit.edu

Meet Mr. Timothy "Tim" Frazier

Mr. Timothy Frazier, an Ohio native, has been a key member of the AFIT family since his arrival as a Master Sergeant in 2005. Prior to joining AFIT, Mr. Frazier served as a member of the security forces.

"Being a cop, and growing up as a cop in the Air Force, being put into this, academia, it was a culture shock. The culture at AFIT is collaborative. Everyone is looking to reach out and get others involved; to reach students of all ages through events such as Engineers Week."



Mr. Timothy Frazier at the Air Force Institute of Technology (AFIT), Wright-Patterson AFB.

Since his arrival at AFIT, Mr. Frazier has spent time in Mission Support (MS), AFIT Civilian Institution Programs (CI), and most recently in the Office of the Dean for the Graduate School of Engineering and Management (EN).

> "The culture at AFIT is collaborative. Everyone is looking to reach out and get others involved; to reach students of all ages through events such as Engineers Week."

When asked about his experience at AFIT, Mr. Frazier stated, "Working in the Dean's office has been the best job I've had. It has given me the opportunity to see and interact with multiple sections of AFIT and to work with the Civil Engineering (CE) and School of Systems and Logistics (LS)."

Many around AFIT recognize Mr. Frazier from the numerous tours that he leads for visitors and guests of AFIT. "The tours have been the most fascinating part of my job; the most eye-opening. They have allowed me to see both the education provided at AFIT and how our faculty and students use the education to provide solutions to the Air Force community."

Mr. Frazier stresses to each visitor that AFIT is the Air Force's graduate school for officers and civilians. "The research accomplished here is fascinating and used to advance not just the Air Force, but our sister organizations as well."

As AFIT enters its centennial year, Mr. Frazier looks forward to celebrating this momentous occasion with all those at AFIT. He states, "I am proud of the organization I represent. I am proud to be a part of the history that AFIT has and that can be seen when walking through the halls. Our alumni include astronauts, accomplished academics, Air Force Officials, researchers and more.
It is both an honor and fun when an AFIT graduate returns to visit and I get to lead the tour. During AFIT's 100th anniversary, I will be excited to learn more about our history; to see the displays that are being created and to hear from Senior Leaderships about what they envision for AFIT, the role we play and what we will continue to do for our nation."

DID YOU KNOW?

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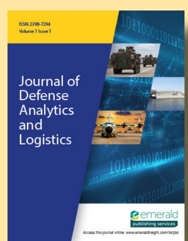

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AFIT Faculty Highlight: Dr. Mullins Awarded Patent

Dr. Barry Mullins
Department of Electrical and Computer Engineering

AFIT alumni Major Benjamin Ramsey (PhD Computer Science, 2014 and M.S. Electrical Engineering, 2009) and AFIT Professor of Computer Engineering Dr. Barry Mullins (M.S. Computer Engineering, 1987) were awarded U.S. Patent #10,111,094 for Wireless Intrusion Detection and Device Fingerprinting Through Preamble Manipulation.

Summary of the invention:

Wireless networks are particularly vulnerable to spoofing and route poisoning attacks due to the contested transmission medium. Embodiments of the invention demonstrate a novel and complementary approach to exploiting physical layer differences among wireless devices that is more energy efficient and invariant with respect to the environment. Specifically, the embodiments exploit subtle design differences among transceiver hardware types. Transceivers fulfill the physical layer aspects of wireless networking protocols, yet specific hardware implementations vary among manufacturers and device types. Precise manipulation of the physical layer preamble may assist in preventing a subset of transceiver types from receiving the modified packet. By soliciting acknowledgments from wireless devices using a small number of packets with modified preambles, a response pattern identifies the true transceiver class of the device under test. Herein the embodiments demonstrate a transceiver taxonomy of eight manufacturers into seven classes with greater than 99% accuracy, irrespective of environment. Wireless multi-factor authentication, intrusion detection, and transceiver type fingerprinting through preamble manipulation is successfully demonstrated.

Embodiments of the invention provide a hardware environment and a method for establishing hardware identity of a coordinating device in a wireless network by a joining device. A standard PHY preamble is modified by the joining device to a preamble that can be received by the coordinating device having an expected hardware configuration. The modified PHY preamble is transmitted to the coordinating device with an association request by the joining device. If a response containing an association response from the coordinating device is not received by the joining device, the hardware configuration of the coordinating device is determined to not be the expected hardware configuration.

Dr. Barry Mullins

In some embodiments, if, in response to receiving a reply from the coordinating device, the standard PHY preamble is modified to a second modified preamble that can be received by the coordinating device having the expected hardware configuration and transmitted with a data request to the coordinating device. If a response containing an acknowledgment response from the coordinating device is not received by the joining device, the hardware configuration of the coordinating device is determined to not be the expected hardware configuration.

Embodiments of the invention may also be used to characterize a hardware identity of a device in a wireless network. A request with a modified PHY preamble is transmitted to the device. If a reply is received from the device, the device is characterized as a first hardware type. If no reply is received from the device, characterizing the device as not the first hardware type.

In some embodiments were no reply is received, a request is transmitted with a second modified PHY preamble different from the first modified PHY preamble. If a reply is received from the device, the device is characterized as a second hardware type. If no reply is received from the device, the device is characterized as not the first or second hardware type.

AFIT Faculty Highlight: Dr. Collins Receives Award

Dr. Peter Collins

Dr. Peter Collins
Department of Electrical and Computer Engineering

Dr. Collins was selected to receive the Distinguished Achievement Award at the Antenna Measurement Techniques Association (AMTA) Symposium Awards Banquet in November 2018. This is the highest award given by the Antenna Measurement Techniques Association.

Past honorees include Dr. Chi-Chih Chen (OSU), Dr. Brian Kent (Former AFRL STS), and Dr. Yahya Rahmat-Samii (UCLA).

AFIT Student Highlight: PhD Student Thesis

Major Aaron Lessin
Department of Operational Sciences

Maj Lessin produced the thesis: "Multi-Level Multi-Objective Programming and Optimization for Integrated Air Defense Disruption" during his doctoral studies at AFIT. This research develops and demonstrates the application of sensor location, relocation, and network intrusion models to provide the mathematical basis for the strategic engagement of emerging technologically advanced, highly-mobile, Integrated Air Defense Systems.

The first phase of research develops bilevel mathematical programming formulations to locate a heterogeneous set of sensors to maximize the minimum exposure of an intruder's penetration path through a defended region. Models are applied to a test instance for the air defense of a border region against intrusion by an enemy aircraft, and alternative intruder routing solutions are examined.

The second phase considers two subsets of sensors that have been respectively incapacitated or degraded, and it develops a multi-objective, bilevel optimization model to relocate surviving sensors to maximize an intruder's minimal expected exposure to traverse a defended border region, minimize the maximum sensor relocation time, and minimize the total number of sensors requiring relocation. Solution procedures are demonstrated for a scenario in which a defender is relocating surviving air defense assets to inhibit intrusion by a fixed-wing aircraft, identifying non-inferior solutions.

Major Aaron Lessin

The third phase of research formulates a trilevel mathematical programming formulation in which an attacker respectively identifies a subset of the defender's heterogeneous sensors to incapacitate and a subset of the defender's network to degrade, subject to budget constraints; a defender subsequently relocates the surviving sensors, considering multiple, competing objectives; and, in the third level, the attacker selects an optimal intrusion path to traverse through the sensor network. As an optimal solution is computationally elusive, heuristics are developed and tested on synthetic, representative scenarios.

DISTINGUISHED ALUMNI

Major General William T. "Bill" Cooley, USAF
PhD Applied Physics, 1997
Commander, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio

Career Highlights:

- August 2015 – April 2017, Program Executive for Programs and Integration, Missile Defense Agency, Redstone Arsenal, Ala.
- June 2013 – July 2015, Director, Global Positioning Systems Directorate, Space and Missile Systems Center, Air Force Space Command, Los Angeles AFB, Calif.
- July 2010 – June 2013, Commander, Phillips Research Site and Materiel Wing Director, Space Vehicles Directorate, Kirtland AFB, N.M.

Major General Carl E. Schaefer, USAF
Deputy Commander, Headquarters Air Force Materiel Command, Wright-Patterson AFB, Ohio. *Selected for assignment to Commander, Air Force Test Center, Air Force Materiel Command, Edwards Air Force Base, Calif.*

Career Highlights:

- March 2015 – July 2018, Commander, 412th Test Wing, Edwards AFB, Calif.
- February 2014 – March 2015, Special Assistant to the SECAF/CSAF for F-35 Integration, the Pentagon, Washington, D.C.
- July 2012 – February 2014, Wing Commander, data masked
- Command pilot with more than 3,000 flying hours in over 30 aircraft types, including combat missions in support of operations Deny Flight and Allied Force

Brigadier General Philip A. Garrant, USAF
M.S. Systems Engineering, 2004
Vice Commander, Space and Missile Systems Center, Los Angeles Air Force Base, Calif.

Career Highlights:

- May 2014 – June 2017, Director, Space Superiority Systems Directorate, Space and Missile Systems Center, Los Angeles AFB, Calif. (AFSPC)
- October 2013 – April 2014, Deputy Director for Regional Teams, Operational Contract Support and Chief, Audit Readiness; HQ USFOR-A; Kabul, Afghanistan and Al Udeid, Qatar
- July 2011 – May 2014, Senior Material Leader, EELV Systems Division, Space and Missile Systems Center, Los Angeles AFB, Calif. (AFSPC)

Information and photos from www.af.mil unless otherwise noted

Brigadier General Linda S. Hurry, USAF
M.S. Transportation Management, 1995
Commander, Defense Supply Center Richmond and Defense Logistics Agency Aviation, Richmond, Va. *Selected for assignment to Director, Logistics, Deputy Chief of Staff for Logistics, Engineering and Force Protection, Headquarters United States Air Force, Pentagon, Washington, D.C.*

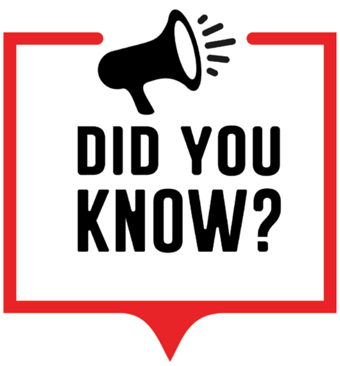
Career Highlights:

- August 2016 – June 2017, Director, Expeditionary Support, Air Force Installation and Mission Support Center, JB San Antonio-Lackland, Tex.
- July 2014 – August 2016, Commander, 635th Supply Chain Operations Wing, Scott AFB, Ill.
- August 2013 – July 2014, Deputy Commander for Maintenance, Oklahoma City Air Logistics Complex, Tinker AFB, Okla.

Brigadier General Rodney D. Lewis, USAF
M.S. Strategic Leadership, 2006
Director, Secretary of the Air Force and Chief of Staff of the Air Force Executive Action Group, Headquarters U.S. Air Force, the Pentagon, Arlington, Va.

Career Highlights:

- July 2015 – April 2017, Wing Commander, 319 Air Base Wing, Grand Forks, N.D.
- August 2014 – June 2015, Vice Commander, 3rd Wing, Joint Base Elmendorf-Richardson, Alaska
- September 2012 – June 2014, U.S. Transportation Command, Chief, Legislative/Interagency Affairs, Washington, D.C.



AFIT ALUMNI CAN EASILY UPDATE CONTACT INFO ONLINE

Just visit the AFIT website at the below link, click on the "Update Your Contact Info" tab on the right side and fill out the online form.

www.afit.edu/ALUMNI

Information and photos from www.af.mil unless otherwise noted

Colonel Eileen A. Bjorkman, USAF, Retired, PhD, SES
M.S. Aeronautical Engineering, 1986; B.S. Aeronautical Engineering, 1982
Deputy Director, Test and Evaluation, Headquarters United States Air Force, Pentagon, Washington, D.C.

Career Highlights:

- February 2017 – July 2018, Deputy Director of Programs, Deputy Chief of Staff for Strategic Plans, Programs and Requirements, Headquarters U.S. Air Force, the Pentagon, Arlington, Va.
- January 2015 – February 2017, Deputy Director of Operations, Directorate of Air, Space and Cyberspace Operations, Headquarters Air Force Materiel Command, Wright-Patterson AFB, Ohio
- September 2013 – January 2015, Private sector, Everett, Wash.

Colonel Edwin H. Oshiba, USAF, Retired, SES
M.S. Engineering & Environmental Management, 1997
Director of Resource Integration, Deputy Chief of Staff for Logistics, Engineering and Force Protection, Headquarters U.S. Air Force, Arlington, Va.

Career Highlights:

- February 2015 – January 2018, Deputy Director of Civil Engineers, Directorate of Civil Engineers, Deputy Chief of Staff for Logistics, Engineering and Force Protection, Headquarters U.S. Air Force, Washington, D.C.
- October 2014 – February 2015, Chief, Installation Strategy and Plans Division, Directorate of Civil Engineers, Deputy Chief of Staff for Logistics, Installations and Mission Support, Headquarters U.S. Air Force, Washington, D.C.
- April 2013 – September 2014, Chief, Installation Strategic Plans and Programs Division, Office of the Air Force Civil Engineer, Deputy Chief of Staff for Logistics, Engineering and Force Protection, Headquarters U.S. Air Force, Washington, D.C.

Information and photos from www.af.mil unless otherwise noted

Colonel M. Riley Repko, USAF, Retired
B.S. Electrical Engineering, 1981
Strategic Adviser to the Air Force Secretary and Chief of Staff on innovation and modernization issues to existing and future requirements serving at Headquarters U.S. Air Force, Washington, D.C.

Career Highlights:

- 2011 – 2017, senior research Fellow in cyber security, Virginia Tech Research Center, Arlington, Va.
- February 2009 – November 2011, Senior Adviser, Cyber Operations and Transformation, Deputy Chief of Staff for Operations, Plans and Requirements, Headquarters U.S. Air Force, Washington, D.C.
- January 2006 – August 2006, mobilization assistant to the Deputy Chief of Air Force Reserve, the Pentagon, Arlington, Va.

Dr. Glenn Sjoden
M.S. Nuclear Engineering, 1992
Chief Scientist, Air Force Technical Applications Center, Patrick AFB, Fla.

Career Highlights:

- November 2010 – June 2014, Tenured Professor and Director, Radiological Science and Engineering Laboratory, Georgia Institute of Technology, Atlanta, Ga.
- March 2004 – October 2010, Tenured Associate Professor, University of Florida, Nuclear and Radiological Engineering and Florida Power & Light Professor, Gainesville, Fla.
- May 2001 – March 2004, Deputy Director, Materials Technology Directorate, Air Force Technical Applications Center, Patrick AFB, Fla.

DID YOU KNOW?

Nearly 600 Air Force Institute of Technology (AFIT) alum are currently working at the Air Force Research Laboratory (AFRL) which is also located at Wright-Patterson AFB, Ohio.

Information and photos from www.af.mil unless otherwise noted

Selected Large Awards for Fiscal Year 2018

"Strategic Development Planning & Experimentation Support: Roadmap for Multi-Domain Modeling, Simulation, Analysis and Experimentation" $700K; SDPE; Principal Investigator: Dr. Jeffrey Weir

"Air Force Institute of Technology Center for Operational Analysis Support to Acquisition Intelligence Requirements Task Force (AIRTF) for Intelligence Mission Data (IMD) Cost, Capability Analysis (CCA)" $537K; Office of the Secretary of Defense; Principal Investigator: Dr. Jeffery Weir

"High Resolution Magnetic Mapping and Modeling" $500K; National Geospatial-Intelligence Agency; Principal Investigator: Capt Aaron Canciani

"T-6 Subject Matter Expertise Engineering Support" $500K; Air Force Life Cycle Management Center; Principal Investigator: Dr. Darryl Ahner

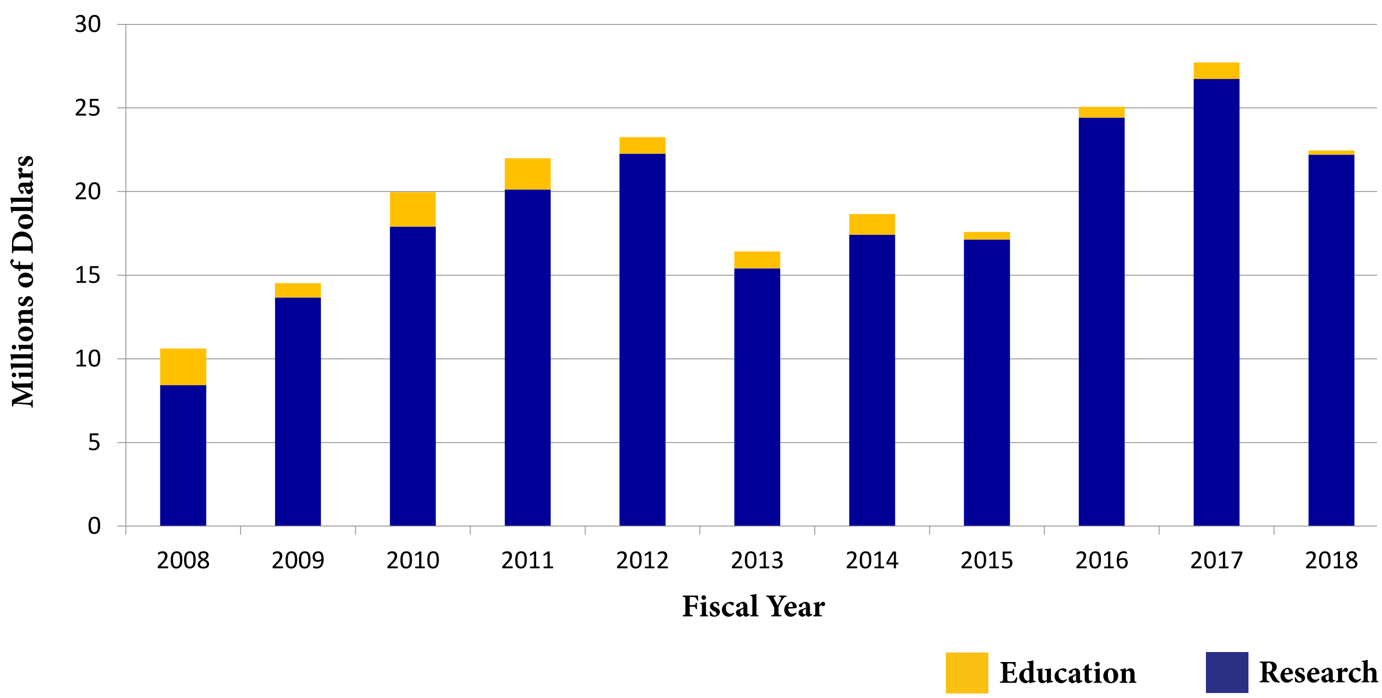
"Air Force Installation and Mission Support Center, RMO Analysis Support" $450K; Air Force Installation and Mission Support Center; Principal Investigator: Dr. Jeffrey Weir

"Navigation for A2AD, Long Range, Over Water Ingress" $400K; Air Force Research Laboratory; Principal Investigator: Capt Aaron Canciani

"CY2018 DE JTO AP TAWG Research and Analysis" $400K; Directed Energy Joint Technology Office; Principal Investigator: Dr. Steve Fiorino

"CY2018 DE JTO M&S TAWG Product Development" $400K; Directed Energy Joint Technology Office; Principal Investigator: Dr. Steve Fiorino

New Award History Fiscal Year 2008 - Fiscal Year 2018

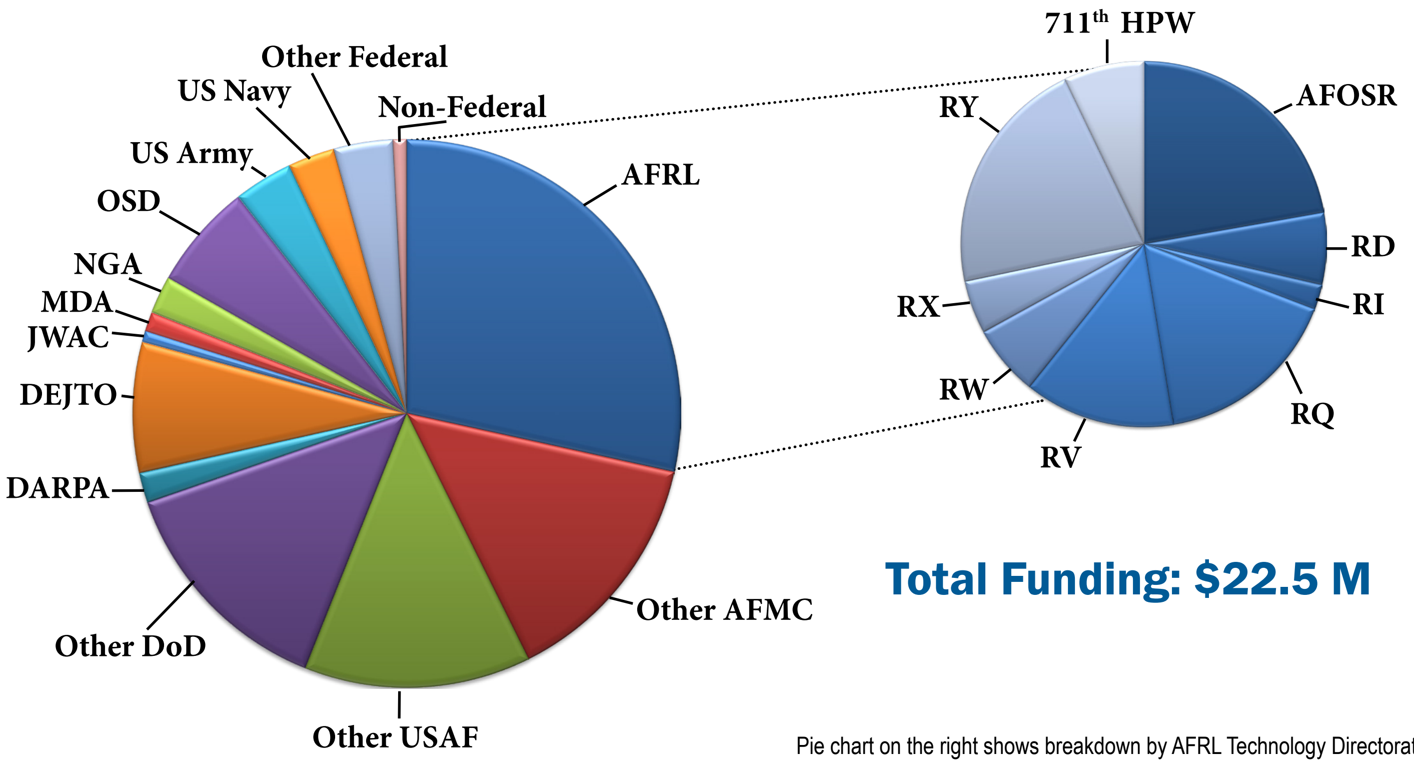


New Fiscal Year 2018 Awards to Academic Departments and Research Centers

	Newly Awarded Research Projects		Newly Awarded Education Projects		Total FY18 Newly Awarded Projects		Total FY18 Research Expenditures
DEPARTMENTS	**#**	**$k**	**#**	**$k**	**#**	**$k**	**$k**
Mathematics & Statistics (ENC)	9	554	-	-	9	554	544
Electrical & Computer Eng (ENG)	55	5,774	3	150	58	5,924	5,794
Engineering Physics (ENP)	46	5,743	1	8	47	5,751	5,836
Research & Sponsored Programs (ENR)	1	88	-	-	1	88	-
Operational Sciences (ENS)	33	6,144	3	221	36	6,365	7,076
Systems Eng & Management (ENV)	13	869	1	150	14	1,019	1,074
Aeronautics & Astronautics (ENY)	51	2,659	2	99	53	2,758	3,289
TOTAL	**208**	**21,831**	**10**	**628**	**218**	**22,459**	**23,613**
CENTERS	**#**	**$k**	**#**	**$k**	**#**	**$k**	**$k**
Autonomy and Navigation Technology (ANT)	31	3,871	2	120	33	3,991	4,167
Center for Cyberspace Research (CCR)	15	1,185	-	-	15	1,185	936
Center for Directed Energy (CDE)	20	2,957	1	8	21	3,965	2,799
Center for Operational Analysis (COA)*	16	2,937	1	90	17	3,027	3,198
Center for Space Research and Assurance (CSRA)	29	1,902	1	20	30	1,922	2,347
Center for Tech Intel Studies & Research (CTISR)	12	1,510	-	-	12	1,510	1,633
TOTAL	**123**	**14,362**	**5**	**238**	**128**	**14,600**	**15,080**

Note: Total research expenditures reported include institutional cost sharing, which is not included in newly awarded projects. Numbers reported to the ASEE and NSF research expenditure surveys vary somewhat due to differences in definitions. All center funds are also included in departmental funding.

Sponsors of Fiscal Year 2018 Projects



Total Funding: $22.5 M

Pie chart on the right shows breakdown by AFRL Technology Directorates.

Enrolling at AFIT for Graduate Studies

The Graduate School of Engineering and Management offers multiple graduate and doctoral degree opportunities that focus on high-quality graduate education and research. We serve the Air Force as its graduate institution of choice for engineering, applied sciences, and selected areas of management. The appeal for our distinct educational opportunities is widespread and attracts high-quality students from other US armed services, Government agencies both inside and outside the DoD, and international military students.

Of particular note, under the National Defense Authorization Act for Fiscal Year 2011, the Graduate School may enroll defense industry employees seeking a defense-related master's or doctoral degree. Tuition will be waived for all Air Force military and Air Force civilians, who are not sponsored by the Air Force to enroll at AFIT on a space-available basis.

Our automated application system provides immediate application information to the Office of Admissions, and there is no application fee. Because of our highly-automated admission processes, the Office of Admissions usually renders an admission decision within 21 days.

Prospective students will join a robust and energetic student body focused on learning and research. Enrollment averages around 700 full and part-time students with a student-to-faculty ratio of 6:1. In the academic year 2015-2016, 337 master's and doctoral degrees were awarded to 253 AF officers, 3 AF enlisted, 28 sister services, 41 civilians, and 12 international military officers. Students usually finish their master's programs within two years and the doctoral programs within three years.

The AFIT campus consists of eight buildings, 23 class laboratories, 67 research/laboratory areas, and the D'Azzo Research Library.

For more information, visit the AFIT Office of Admissions webpage: **www.afit.edu/admissions.**

DID YOU KNOW?

The Engineering Accreditation Commission (EAC) and the Applied Science Accreditation Commission (ASAC) of ABET accredits AFIT's eligible engineering and applied science programs.

AFIT Internship Opportunities

Internship opportunities are available for undergraduate and graduate science, technology, engineering, and mathematics (STEM) students through the Southwestern Ohio Council for Higher Education (SOCHE). Students have the opportunity to work at AFIT through the Summer Internship Program, the Student Research Program, or both. Students benefit both academically and financially by working in state-of-the-art laboratories with top professionals in their field. Additionally, they can use this experience for senior projects, cooperative education, and graduate research. AFIT receives the benefit of top students, who bring new energy and ideas to the research projects.

SOCHE

For information regarding AFIT internship opportunities visit: **www.socheintern.org.**

AFIT RESEARCH CENTERS

Autonomy and Navigation Technology Center	**www.afit.edu/ANT**
Center for Cyberspace Research	**www.afit.edu/CCR**
Center for Directed Energy	**www.afit.edu/CDE**
Center for Operational Analysis	**www.afit.edu/COA**
Center for Space Research and Assurance	**www.afit.edu/CSRA**
Center for Technical Intelligence Studies & Research	**www.afit.edu/CTISR**
OSD Scientific Test and Analysis Techniques Center of Excellence	**www.afit.edu/STAT**

Sponsoring Thesis Topics

AFIT encourages input from your agency that aligns our research and student education to relevant areas to ensure the technological superiority and management expertise of the U.S. Air Force and the DoD. Each topic submitted has a strong positive impact on AFIT's ability to focus on research relevant to real-world requirements. For more information, please email the Office of Research and Sponsored Programs: **research@afit.edu**.

AFIT Directory

For specific information regarding faculty research areas, please see the Faculty Directory and Expertise Search page at: **www.afit.edu/directory_search.cfm**.

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