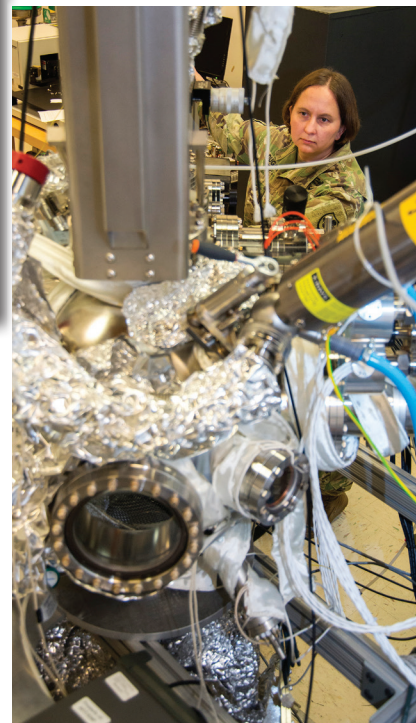
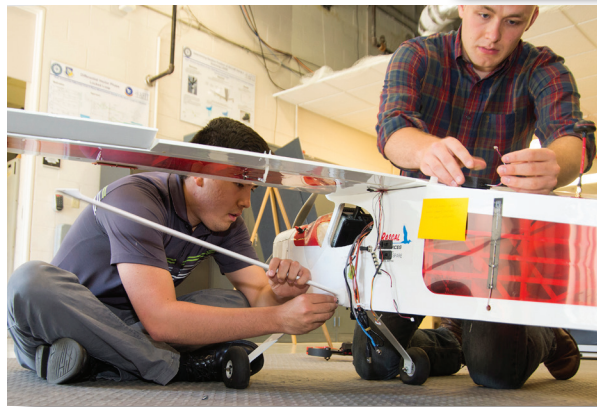
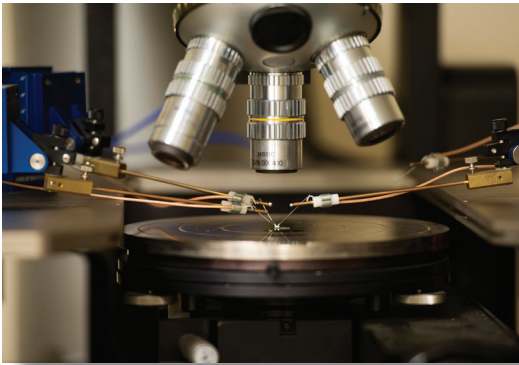
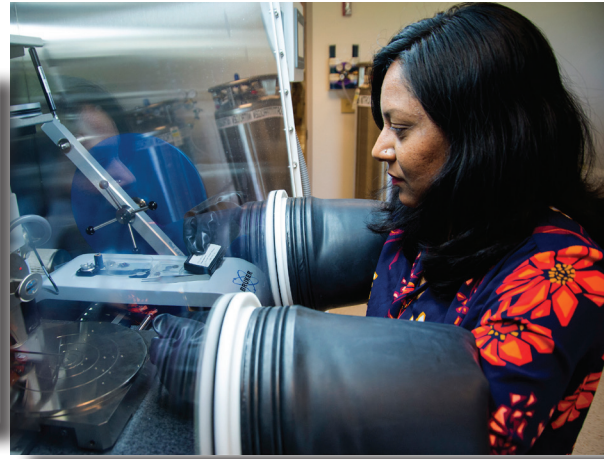
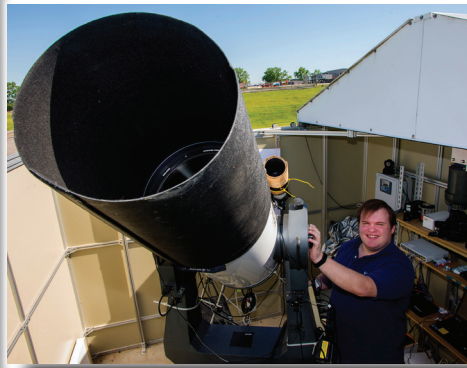
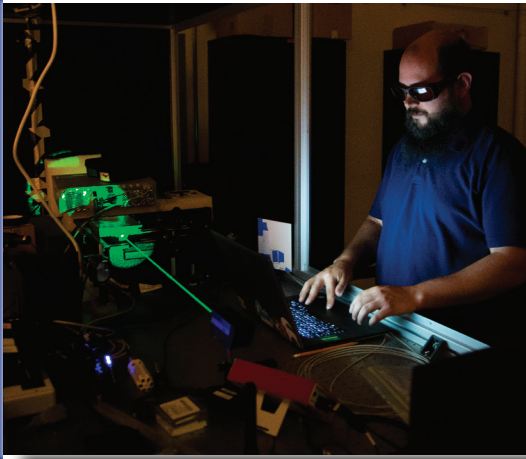


# 2017 ANNUAL REPORT

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



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## 2017 Annual Report

# A MESSAGE FROM THE DEAN

Welcome to the 2017 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 additive manufacturing (3-D Printing) in this annual report. The coverage highlights how AFIT has taken a leading role in leveraging additive manufacturing to support US Air Force missions at home and abroad. In October, we hosted a special symposium on Digital Engineering & Manufacturing Enterprise (DEME), in which additive manufacturing was the main feature. Sessions in the symposium highlighted how researchers and practitioners are enabling additive manufacturing in the aerospace and defense sector. The emergence of the “new-collar” workforce (knowledge workers) makes it imperative that we direct our attention and resources to developments in additive manufacturing, which will reshape and revitalize manufacturing enterprises. The Defense Industry will be the cornerstone of this new digital engineering revolution. I am delighted that AFIT is playing a leading national role in workforce development for additive manufacturing from a systems integration viewpoint, encompassing science, technology, engineering, and mathematics.

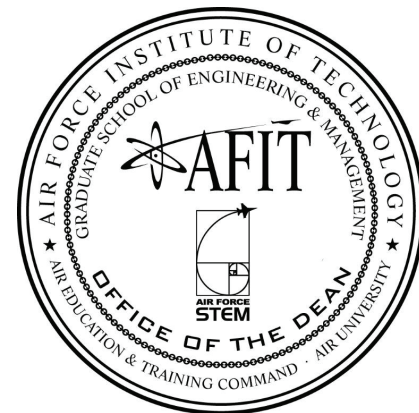
Manufacturing is rapidly shifting from manual labor to digital work. The digital revolution is now cross-hatched with conventional manufacturing. What was previously limited to the realm of laboratory research has now been transformed to the platform of practical reality. For decades, manufacturing had languished within the same old framework of mold-and-cast type of product development. That traditional approach has made manufacturing subject to the inability to respond quickly and adaptively to new operational requirements. With the advent of additive manufacturing (also known as Direct Digital Manufacturing), product designers now have a tool to respond to the requirements for new on-site intricately-designed products. AFIT’s Graduate School of Engineering and Management is thrilled to be taking a leading role in the related research and advanced education. In this regard we partner aggressively with collaborators in government, industry, business, and civilian universities.

Through this annual report, please join us on our journey of excellence in meeting the needs of the warfighter. We look forward to your continuing engagement and advocacy for our academic and research programs.

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



# AFIT Looks to the Future

## AFIT Symposium Focuses on Future Impact of Additive Manufacturing

*Originally Posted Monday, November 13, 2017*

The digital engineering and manufacturing environment continues to be a vital component of the relationship between the private and public sectors. Additive manufacturing has revolutionized prototyping and has grown to become one of the more innovative areas in the aerospace, engineering and medical fields.

The Air Force Institute of Technology Graduate School of Engineering and Management recently hosted the Digital Engineering and Manufacturing Environment Symposium: Enabling Additive Manufacturing in the Aerospace and Defense Sector, centered on moving that conversation forward.

The symposium brought together representatives from defense, industry and academia through keynote speakers, informative breakout sessions and a trade show floor representing 37 companies and regional organizations leading the field. Symposium host Dr. Adedeji Badiru, Dean of the Graduate School of Engineering and Management, said this is an important time to be having these conversations about manufacturing.

“The emergence of what IBM calls the new collar workforce makes it imperative that we direct our attention and resources to recent developments in additive manufacturing, which will reshape and revitalize manufacturing enterprises,” Badiru said.

The symposium was held Oct. 30-31 at Wright State University’s Nutter Center. Dr. Paul Hartman, Director of AFIT’s Center of Operational Analysis, served as symposium chair.

“This symposium was specifically designed to spur conversations and strengthen the relationships between the public and private sectors in this field,” Hartman said. “The conversations that took place during the event will ultimately have a lasting impact on how we push forward in manufacturing integration.”

Keynote speakers included Michael Schneider as a representative for Kevin Stamey, Director of Engineering and Technical Management, Air Force Sustainment Center, Tinker Air Force Base, Oklahoma;



Dr. Adedeji Badiru, Capt. Andrew Lingenfelter, Jessica Smith and Maj. Ryan O'Hara stand with samples made from Air Force Institute of Technology's state-of-the-art metal additive manufacturing system. (U.S. Air Force photo/Katie Scott)

and Brig. Gen. Allan Day, Director of Logistics, Civil Engineering and Force Protection Headquarters Air Force Materiel Command, Wright-Patterson Air Force Base. Invited guest speaker Barbara Humpton, President, Siemens Government Technologies, wrapped up the symposium.

“The defense industry will be the cornerstone of this new digital engineering revolution,” Badiru said. “I am delighted that AFIT is playing a leading national role in workforce development for additive manufacturing from a systems integration viewpoint, encompassing science, technology, engineering, and mathematics as well as the visual arts and design disciplines. The human operating environment is changing rapidly,” Badiru said. “This symposium was designed to help coalesce the thoughts and actions needed to fully leverage the wide capabilities of additive manufacturing.”

## New Device can Additively Manufacture Parts for Aerospace Research

*Originally Posted Friday, March 24, 2017 By Amy Rollins, Skywrighter Staff*



Major Ryan O'Hara and Dr. Adedeji Badiru

The Air Force Institute of Technology at Wright-Patterson Air Force Base has been utilizing additive manufacturing, also known as 3D printing, to build prototypes with polymers for more than 30 years. On March 16, its Graduate School of Engineering and Management unveiled a new state-of-the-art metal additive manufacturing system that enables AFIT to digitally fabricate aerospace metal parts. The Concept Laser M2 3D Metal Printer system is a nearly \$1 million investment.

“Metal additive manufacturing employs a laser to melt a finely graded metal powder, layer by layer, to produce components that are fully dense metal”, stated Maj. Ryan O'Hara, Assistant Professor, Graduate School of Engineering and Management, and AFIT's lead for additive manufacturing.

The finely graded metal powder is carefully contained within the machine and added as needed following a strict protocol that minimizes possible exposure to personnel. The process begins with a build plate on which the part is manufactured. Parts from AFIT's printer may be up to roughly 10 inches by 10 inches by 10 inches or smaller.

After the part is manufactured, the fine metal powder is “sieved, Alaskan gold mine-style,” O'Hara said, to remove any small conglomerates and soot and prepare the powder for reuse.

“This is a fairly automated process that is

conducted in an isolated and modular system,” he said. “Other systems may have a lot more user handling of the powder. We chose this one to limit exposure.”

Using this technology, AFIT's research plans will focus on advancing the employment of three primary aerospace metals: inconel - a nickel super alloy titanium and aluminum.

The addition of the new 3D machine allows for AFIT to become an expert in the application of metal additive processes so it is able to make recommendations to the Air Force on the practical implementation of metal additive components for flight-critical air and space applications, O'Hara said.

“Ultimately, this is a capability that enhances the defense focused graduate research that we are already doing, whether that is to produce prototypes faster or get someone into the lab for practical experimentation, those are all things we've traditionally done in polymers to facilitate research and technology applications, and now we're applying these techniques with metal,” he said.



Additive manufacturing processes are known for their ability to fabricate parts with complex geometries. Lattice structures, like the samples shown, leverage this ability to create parts with high strength-to-weight ratio and other desirable structural qualities. The Graduate School of Engineering and Management at the Air Force Institute of Technology, Wright-Patterson Air Force Base, unveiled its new 3D metal additive manufacturing system March 16. (Skywrighter photo/Amy Rollins)

## New Device can Additively Manufacture Parts for Aerospace Research *Continued*

*Originally Posted Friday, March 24, 2017 By Amy Rollins, Skywrighter Staff*



Maj. Ryan O'Hara (right), Assistant Professor, Graduate School of Engineering and Management, Air Force Institute of Technology, Wright-Patterson Air Force Base, demonstrates the capabilities of a new state-of-the-art 3D metal additive manufacturing system to Dr. Todd Stewart, AFIT Director and Chancellor, March 16. The system is a nearly \$1 million investment that enables student researchers to digitally fabricate fully dense aerospace metal parts. (Skywrighter photos/Amy Rollins)

The advantage of the metal additive manufacturing system is it can produce internal structures to traditional metal parts that could not normally be machined, according to O'Hara.

"In a recent project, we were able to decrease weight by 10 to 20 percent while increasing stiffness by 20 to 30 percent," he said. "The big advantage there is we can design lighter and stiffer structures that can respond to aerospace environments while delivering greater capabilities."

AFIT has a number of research areas related to additive manufacturing, specifically work on lattice structures, he said. Before the new machine arrived, production of such structures for research had to be outsourced.

"This is a significant investment for us," said Dr. Todd Stewart, AFIT Director and Chancellor. "We're staying on top of emerging and obviously important technology. I'm excited about that. I understand that this offers somewhat unique capabilities for our Air Force and for our students and faculty."

"This particular machine, in this region,

represents the leading edge of additive manufacturing," said Dr. Adedeji Badiru, Dean, Graduate School of Engineering and Management. "There are many pockets of additive manufacturing around the Dayton area. We are hoping this new capability will lead to collaboration with the Air Force so we can gain more direct applications."

Dr. Eric Swenson, Associate Professor, Department of Aeronautics and Astronautics, said the advantage of the 3D printer is it will allow the user to create the one part he or she needs with all the design freedom he or she desires.

"It's a pretty fantastic way to go," he said. "In the long run, it is a lot less expensive. If you find a little problem area, you can fix it and print it again. You can then iterate to a really interesting, fast solution and build spacecraft parts quickly and easily, totally moving the research forward."

"There is so much we can do. It's going to be exciting when we start getting results and being able to publish papers on novel science that no one else has ever done," said Benjamin Doane, a research assistant at the Center for Space Research and Assurance at AFIT. "The possibilities are endless. We can now start printing parts that we can test and compile their data, it is going to be pretty cool."

The original article is posted in the 24 March 2017 Skywrighter, Vol 58, No. 12 and on the WPAFB news website.

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please contact Dr. Heidi Ries,  
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## AFIT Plans for Accreditation Reaffirmation Process

*Originally Posted Monday, September 18, 2017*

In preparation for its ten-year accreditation reaffirmation by the Higher Learning Commission (HLC) in 2020, the Air Force Institute of Technology (AFIT) welcomed HLC Liaison Dr. Barbara Johnson to campus in August. Dr. Johnson has worked for HLC since 2013 and currently serves as the Vice President for Accreditation Relations. During her visit, Dr. Johnson provided expert guidance on the reaccreditation process, specifically the Assurance Argument and the Quality Improvement Project (QIP).

“During her visit to AFIT, Dr. Johnson engaged with the leadership and also received a thorough exposition of AFIT’s educational and research capabilities and activities. She has expressed her admiration of the institution’s commitment to world-class excellence in all aspects of AFIT’s academic endeavors. In-depth discussions regarding every component of the AFIT’s Higher Learning Commission reaffirmation of accreditation preparation have energized the campus community to diligently march forward with our data collection and learning assessment processes,” said Dr. Sivaguru S. Sritharan, AFIT’s Provost and Vice Chancellor.

HLC conducts an Assurance Review to determine whether an institution continues to meet the Criteria for Accreditation. The institution demonstrates that it meets the Criteria for Accreditation by preparing an Assurance Argument with an Evidence File.

There are five criterion for accreditation: 1) Mission, 2) Integrity: Ethical and Responsible Conduct, 3) Teaching and Learning: Quality, Resources, and Support, 4) Teaching and Learning: Evaluation and Improvement, and 5) Resources, Planning, and Institutional Effectiveness.

Committees comprised of faculty and staff from across AFIT are currently working on each criterion. They are tasked with developing assurance arguments and gathering evidence to demonstrate how AFIT is compliant with each criterion. During Dr. Johnson’s visit, she received status briefings on each criterion, answered committee questions, and provided very helpful feedback on the way forward.

Dr. Johnson also reviewed AFIT’s Quality Initiative Project (QIP). The QIP demonstrates the institution’s commitment to continuous improvement

and is focused on modernizing instructional capabilities across the institute. The QIP committee is developing investment strategy guidance to address five thrust areas: (1) Classroom and teaching laboratory design, functionality, and utilization; (2) E-learning technologies for resident and distance delivery; (3) Faculty and staff development programs and support infrastructure; (4) Infrastructure to support advanced instructional technology capabilities; and (5) Organizational structures, policies, processes, procedures, and strategic vision to support effective teaching. Data collection and gap analysis is complete and the final report is nearing completion.

“Dr. Johnson affirmed that AFIT is making substantial progress and is well within the timeline for completion of the final submission to HLC,” said Dr. Betsy Grimes, AFIT’s Assurance Argument Coordinator.

Following the meetings with Dr. Johnson, each committee is energized and working diligently to incorporate feedback to develop the strongest Assurance Argument possible for accreditation reaffirmation in 2020.



Dr. Todd Stewart (far-left) briefs Dr. Barbara Johnson (far-right) on the uniqueness of AFIT as a military organization with an education mission

## Center for Operational Analysis Looks to the Future

*Originally Posted Tuesday, August 29, 2017*

### **R**oadmap for Multi-Domain Modeling, Simulation, Analysis and Experimentation

Current challenges facing the United States Air Force (USAF) include a limited capability to conduct multi-domain, cross-technology assessments and link these technologies to anticipated contributions to military utility. Concept exploration and development is often limited by program classification and access. There is also a limited number of cross-domain analytical teams tasked and supported with the focused responsibility for cross-core function analysis. A variety of Modeling, Simulation, and Analysis (MS&A) data driven tools are utilized across the Department of Defense (DoD) and USAF, but an overarching effort to develop and integrate these tools is not supported by an informed and efficient process.

The Center for Analysis (COA) supported the Air Force Strategic Development Planning & Experimentation Office (SDPE) by identifying USAF MS&A requirements that are linked to Air Force Enterprise priorities and associated use cases. Supported by a review of current MS&A capabilities and analysis, the COA identified and documented the required MS&A capabilities, investment priorities, and actions needed to create the building blocks for a robust multi-domain MS&A enterprise; to include Tools/Models (T), Data/Infrastructure (D), People/Skills (P), Processes/Methods (P), and Partnerships/Community (P) – referred to as TDP3.

The recommended solution included improved tools that are robust and re-usable, data that is standardized and accessible, people that are trained and matrixed across USAF teams, streamlined and efficient processes, and partnerships that span services, industry, and coalitions. This enhanced TDP3 set is necessary to meet the goals of an integrated simulation environment.

Ultimately, the COA identified an enhanced TDP3 set necessary to meet the goals of an integrated simulation environment to support development planning, capabilities assessment, and acquisition decisions.

### **I**ntelligence, Surveillance, and Reconnaissance (ISR) Futures Sensitivity Analysis and Uncertainty Quantification

The Center for Operational Analysis supported the Air Force Life Cycle Management Center Engineering Design and Analysis Division (AFLCMC/XZE) by conducting a Multi-Objective Decision Analysis (MODA) capability that provided the comparison of cost and capability of Intelligence, Surveillance, and Reconnaissance (ISR) future states.

The ISR Futures planning effort investigated the potential future missions and assessed enabling technologies that may be available for transition and fielding in the 2030 timeframe. This COA conducted a Multi-Objective Decision Analysis (MODA) that provided the comparison of cost and capability. The COA also investigated the sensitivities of various MODA related factors to help decision makers better understand the uncertainties and the sensitivities to those uncertainties within the design space. Sensitivity analysis was performed across different value hierarchies to account for potential future changes to needs and contexts to help identify concepts and solutions that are robust and adaptable. This included predicting future states of customer needs and potential changes in mission environments and scenarios as implemented with adaptive value hierarchies.

Lastly, the MODA model and the uncertainty analysis was integrated into the existing AFLCMC/XZE business process and systems to provide flexibility for follow-on ISR studies within the Air Force and across the DoD. This new capability allows the service to smartly identify technology investments and affordable and effective design concepts.



## Comparing Atmospheric Turbulence Using Time-Lapse Imagery

*Originally Posted Tuesday, August 29, 2017*

### Estimation of turbulence parameters from time-lapse imagery

Commercially available scintillometers have limited operational ranges. Recently there has been a growing interest to investigate alternate methods to measure turbulence over longer paths. Techniques for extracting turbulence information from satellite and radar data have been demonstrated before. Phase based techniques have also been proposed. The advantage of using a phase based technique is that it can be used over longer paths where irradiance based methods such as scintillometry can fail due to saturation problems. The researchers at AFIT's Center for Directed Energy (CDE) have developed a method to estimate turbulence parameters from turbulence induced random, differential motion of different features in the time-lapse imagery of a distant target. Besides being phase-based, this method has an added advantage of remotely sensing turbulence without the need for deployment of sensors at the target location.

An imaging experiment was conducted over a 7km slant path from December, 2016 to February, 2017 to demonstrate the idea. Images of a local building were captured every 40 seconds from behind a window at University of Dayton's Intelligent Optics Laboratory using an electronic camera mounted at the back of a 14 inch telescope with focal length 3.91 m. The differential motion between features in neighboring frames were computed using cross-correlation techniques. The differential signal eliminated the effect of platform vibrations, and only included motion due to turbulence. The variance of the random differential image motion can be expressed as a path weighted integral of the turbulence strength,  $C_n^2$  along the path. By linearly combining variances corresponding to different feature sizes and separations, the time-lapse measurements can be made to mimic the measurements of a scintillometer or any other instrument.

Figure 1 shows the comparison of the time-lapse estimates with measurements from a Scintec BLS2000 scintillometer placed along the same path for 4 different dates. Overall, there is good

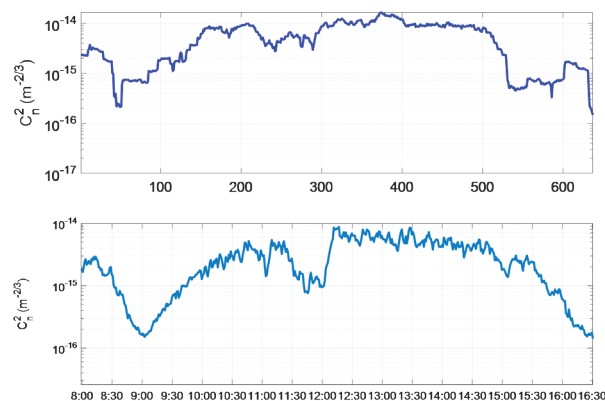


Fig.1. Comparison of time-lapse estimates with scintillometer. Top: Time-lapse estimates from 8 AM to 4:28 PM EDT Dec 29, 2016. Bottom: Scintillometer measurements for the same observation period.

agreement between the two techniques. The small differences can be due to estimation noise from poor contrast in the images, reflection on the windows, the difference in the sensing wavelengths in the two methods, altitude difference between the scintillometer and the windows in the building that are used for estimation and lack of a suitable way to estimate the effective patch size around a corner. Due to lack of enough features to track in a single frame, several frames were used to compute the variance, thus resulting in a temporal averaging effect too.

### Investigating the effect of wind on turbulence anisotropy using Hartmann Turbulence Sensor (HTS)

The HTS comprises of a 16 inch Meade telescope, some imaging lenses, a 32x32 lenslet array and a high speed camera. Light from a He-Ne laser is aberrated due to turbulence and the aberrated wavefront at the pupil plane of the telescope is imaged onto the lenslet array, which focuses the disturbed wavefront into an array of spots at the focal plane of the lenslet array. In the current system, there are 700 active lenslets/ subapertures and hence 700 spots at the focal plane. The camera records the random motion of these spots due to turbulence and the horizontal (x-) and vertical (y-) displacements, or tilts are computed. If turbulence is isotropic, the x- and y- tilts are expected to be independent and a scatter plot of the tilts will be a circle centered at the origin.

# Comparing Atmospheric Turbulence Using Time-Lapse Imagery

## Continued

However, there are two ways in which anisotropy in turbulence can present itself. In one case, the tilt variances are different in the horizontal and vertical directions, as can be expected in a plume or a stratified (layered) structure. A scatter plot of such a scenario is an ellipse with its axes aligned with the x- and y- axes. The other case can be when the tilts in the horizontal and vertical directions are not independent, but correlated to each other in some fashion. The scatter plot in this case will be an ellipse with its major axis oriented at an angle with respect to the x-axis, as shown in Fig. 2. Data taken over a 200 m grassy path in the summer of 2016 showed the second type of anisotropy frequently. In an effort to understand the cause, an experimental campaign was done over a 1 km asphalt runway at the laser experimental range at Wright-Patterson AFB in the summer of 2017 to investigate the role of wind, if any, in steering turbulence eddies along a particular direction, thus breaking symmetry and creating anisotropy. A sonic anemometer was placed along the same path to measure wind speed and direction.

Figure 3 shows the convention used for calculating the wind angle. A correlation between the wind direction and the angle of the major axis of anisotropy was observed during the day with wind speeds around 3 mph or higher. Specifically, the angle tended to be close to 45o or -45o (Fig.8) and it steered in a different direction depending on which way the wind blew across the path. When the wind switched directions such that the wind angle switched sign, the angle of the major axis of anisotropy also changed sign. During the night leading up to dawn and when the wind speed was low there was not a strong correlation with the wind angle.

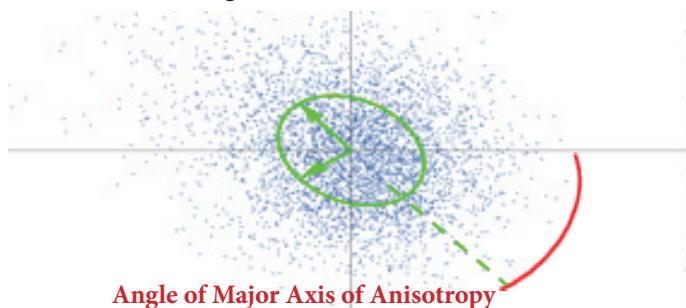


Fig.2. Scatter plot of the tilts obtained from a data set showing the ellipse oriented at an angle with respect to the horizontal, suggesting correlation between the horizontal and vertical tilts.



Fig.3. The experimental path and the convention used for the wind angle

In the future, the time-lapse imaging approach will be validated against simulated imagery. The processing routines will be improved further. The technique will be modified such that the imaging path can be profiled as well. Additionally, field campaigns will be done using AFIT's Hartmann Turbulence Sensor

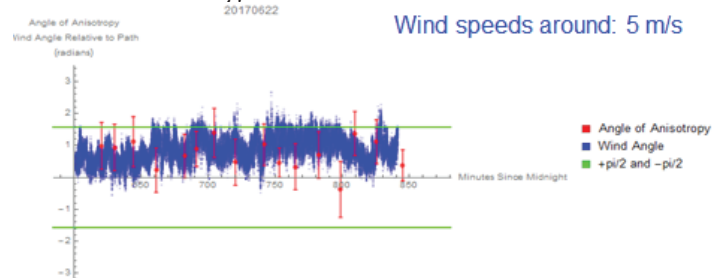


Fig.4. The angle of anisotropy plotted against the wind angle. The wind angle and angle of anisotropy are both positive here.

to better understand the role of the wind on turbulence eddies and to study the behavior of the log-amplitude and phase structure functions over long paths. These results will help improve the analysis further. Figure 5 (below) shows the Hartmann Turbulence Sensor System in its trailer along with additional instrumentation and many of the personnel who carried out these experiments.



## 4D-Resolved, Atmospheric Aerosol Profiling

Dr. Steve Fiorino, Ms. Jaclyn Schmidt and Mr. Kevin Keefer

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Have you ever looked at your city's skyline over a period of successive days and seen a change like that in Figure 1 below? Though its tempting to simply write this off as another case of poor air quality due to too many road vehicles, the underlying causes are a bit more multi-dimensional. Indeed, a progressively murkier skyline over a course of days goes beyond simply an accumulation of carbon-based pollutants in the air. First, such pollutants are but one type of atmospheric aerosol, which collectively range in size from  $\sim 0.001\mu\text{m}$  –  $100\mu\text{m}$ . Furthermore, the multiple types have varying chemical composition, shape, and affinity towards and absorption of ambient atmospheric moisture. In turn, the latter characteristic, known otherwise as hygroscopicity, is linked to aerosol growth and increased light extinction—largely light scatter in the visible through short-wave infrared. Light scatter reduces scene contrast (e.g. a sensor's capability to positively identify a particular building) and a laser's intensity downrange whether employed to illuminate a target for a conventional, Hellfire air-to-surface missile, or directly to blind an incoming missile's guidance system.



Fig. 1 Dayton skyline as observed from AFIT

Though aerosol concentrations are generally uniform in the first 500 – 2000m above the earth's surface, relative humidity increases with altitude to approximately 100% near the top of this otherwise “well-mixed” surface boundary layer (BL). Beyond this altitude, relative humidity decreases dramatically. Depending on the relative proportion of hygroscopic, moisture-absorbing aerosol, one would anticipate an increase in extinction with altitude until one reaches the top of the BL at which point such extinction would fall off in response to the drop in relative humidity. You might have looked out your aircraft window like that depicted in Figure 2 and seen this effect. This phenomenon is also captured with highly precise

LIDAR measurement as depicted in Figure 3.

Engineering environmental simulations far too often choose to allow all common meteorological parameters—and hence the optical effects associated with transmission at the top of the atmospheric boundary layer

constituents—to monotonically decay with height above the surface based on ‘standard’ atmospheric profiles of relative humidity, temperature, and pressure (i.e. the US Standard Atmosphere, 1976). This assumption can lead to significant deviations from reality in the case of BL aerosol optical effects. For the joint mission planner responsible for developing either an intelligence, surveillance, and reconnaissance collection plan employing the best mix of radar, visible or infra-red sensor, or a strike package having the optimum mix of conventional versus speed of light weaponry, having high fidelity foresight on such light scattering is without question preferred.

There are many techniques one can use to assess aerosol optical effects in the field. These techniques can be both active (i.e. illuminating the intended object of investigation) and passive. Active techniques generally provide higher fidelity, like the LIDAR-based vertical profile of aerosol extinction in Figure 3 above. On the other hand, as with any “active” technique, these typically carry a bigger logistic and safety footprint and can be relatively more complex, costlier to procure.

For those seeking concealment, “active” approaches tend to help the adversary identify one's location or point of interest. Passive approaches generally rely on ambient light or other energy sources to illuminate the aerosol media. Indeed, sun photometers have been in use for many decades to study aerosols and their number concentrations, optical effects, and microphysical properties are evaluated based on capturing direct or scattered sun light.

NASA's Goddard Space Flight Center manages a worldwide federated network of sun photometers and associated processing capabilities,



Fig. 2 A birds-eye view of aerosol light extinction (grey area) and a distinctive increase in (blue) light transmission at the top of the boundary layer

## 4D-Resolved, Atmospheric Aerosol Profiling *Continued*

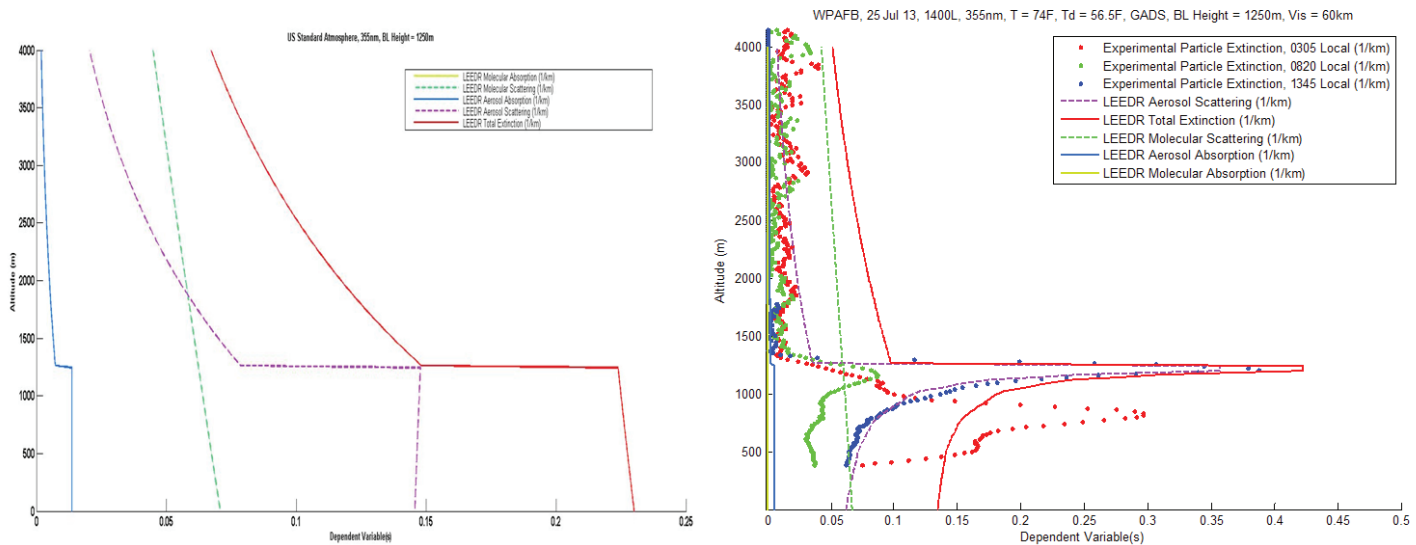


Fig. 3. Vertical aerosol extinction profiles: a.) observed using a RAMAN 355nm LIDAR; and b.) modeled using LEEDR atmospheric characterization and radiative transfer code. (Dayton, 1400 EDT, 25 Jul 13)

which scientists and engineers tap into frequently. Naturally, one's logistic and safety footprint is diminished, but at the expense of availability—cloudy/topographical obstruction and nighttime—and vertical resolution of extinction gradients. The sun photometer is a very capable instrument but its outputs represent the total, composite, surface to top-of-the-atmosphere aerosol extinction and other optical and microphysical properties derived on use of inversion techniques.

Still another technique involves particle counting, which strictly speaking is active but has many passive characteristics as well. Most particle counting designs involve drawing ambient particles into an internal chamber where laser light scatters on engaging passing particles. To aid in ensuring an accurate count, an active agent such as alcohol is introduced to be absorbed by the aerosols, thus enlarging their size and subsequent laser scattering efficiency.

This type of particle counter is referred to as a condensation particle counter (CPC). The scattered light event is sensed and a number concentration derived. The counters are augmented with size spectrometers which enable cataloging of size number distributions. The technology is quite prolific, and motivated by applications ranging from clean-rooms, workplace air quality, and environmental monitoring.

Though having a smaller footprint (literally, size and weight, as well as power consumption, etc.) and not as costly as LIDAR profilers, particle counters are inherently limited to evaluating size and numbers and

at a single point. Thus, to replicate the LIDAR's vertical (and horizontal) sampling of aerosol extinction profiles one might imagine the necessity of employing multiple counters at many altitudes. Even then, one still has to apply first-principles light scattering theory to derive light extinction from size-number data.

The Center for Directed Energy (CDE) has developed a capability which merges the point-wise, but lower footprint particle counter, with the CDE-developed, Laser Environmental Effects Definition and Reference (LEEDR) tool. LEEDR's development has been sponsored by the DoD High Energy Laser Joint Technology Office and several Service agencies and is a verified and validated, fast-calculating, first principles atmospheric characterization and radiative transfer package.

LEEDR enables the creation of highly resolved vertical profiles of temperature, pressure, water vapor content, optical turbulence, and atmospheric aerosols and hydrometeors as well as the ensuing line-by-line, layer-by-layer extinction coefficient magnitude at any wavelength from the ultraviolet to radio frequencies. Distinctively, LEEDR enables a temporally and spatially varying atmospheric boundary layer (BL) through the use of its correlated, probabilistic, global climatological databases inclusive of both meteorological and aerosol data. This allows LEEDR to produce profiles of meteorological data and effects that could actually occur or have actually occurred at a particular location and time, and attach the statistical likelihood of such

occurrence for that time and place.

Additionally, a National Oceanic and Atmospheric Administration (NOAA) Operational Model Archive Distribution System (NOMADS) data feed has been incorporated to supply gridded current/archival observations or real-time, correlated weather forecasts (out to 180 hours) for use in profile generation. Significantly, this capability has been used to considerably strengthen the predictive as well as forensic performance of LEEDR, whether outputting optical turbulence or vertical structure of aerosol extinction profiles when coupled with surface observations. Until recently, the typical surface observation inputs were standard meteorological parameters including temperature, pressure, and relative humidity. Now, one can also enter a scale factor which modifies the climatological surface aerosol concentration associated with one's location of interest according to the actual measured value.

As discussed earlier, use of a CPC enables measurement of the actual aerosol loading regardless of sky condition or sun position. Using the CPC's output enables one to correctly scale climatological aerosol loading for input into LEEDR's highly resolved vertical extinction calculations, thus giving a very realistic basis for assessing sensor and high energy laser system performance.

Figure 4 illustrates the change in near-total aerosol particle counts in Dayton, OH over a 10-day period, 12 Apr to 21 Apr 16 (right side plot). The condensation particle counter (CPC) clearly shows particle counts climbed from under 10,000  $\text{cm}^{-3}$  to over 50,000  $\text{cm}^{-3}$  in the precipitation-free period from 12 to 18 Apr 16. The summer climatological normal in LEEDR's Global Aerosol Dataset database for the Dayton area is  $\sim 35,000 \text{ cm}^{-3}$ .

Thus an aerosol number concentration scale factor of 0.27 is used to match

the LEEDR-derived aerosol optical depths/transmissions to those obtained from sun photometers on 12 Apr 16 (upper left in Figure 4). Additionally, that 0.27 scale factor, or "multiplier," is used to match the LEEDR-derived vertical extinction profile (dashed red line) to the 12 Apr LIDAR-derived profile (solid red line), as seen in the lower left plot of Figure 4.

CDE staff and graduate students are taking steps to validate these initial findings under different ambient conditions, whether associated with alternate locations, climates, and/or seasons. Whereas, the initial field tests were focused on the Dayton area in the spring, follow-on testing is planned for other seasons and at various CONUS / OCONUS locations. Additionally, while the initial assessment of the LEEDR – CPC combination was largely benchmarked by comparing LEEDR derived aerosol extinction vertical profile to LIDAR measurements, work will continue on efforts to demonstrate the LEEDR – CPC capability towards matching and/or assessing field sensors and their imaging performance. The LEEDR – CPC combination will also be applied to high energy laser field testing, via the CDE-developed High Energy Laser End to End Operational Simulation (HELEEOS) model, which includes LEEDR.

Beyond these nearer-term plans, CDE staff foresee this capability being fielded as a tactical decision aid, which will rely on first principles modeling and simulation as well as a network of low footprint surface-based aerosol particle counters.

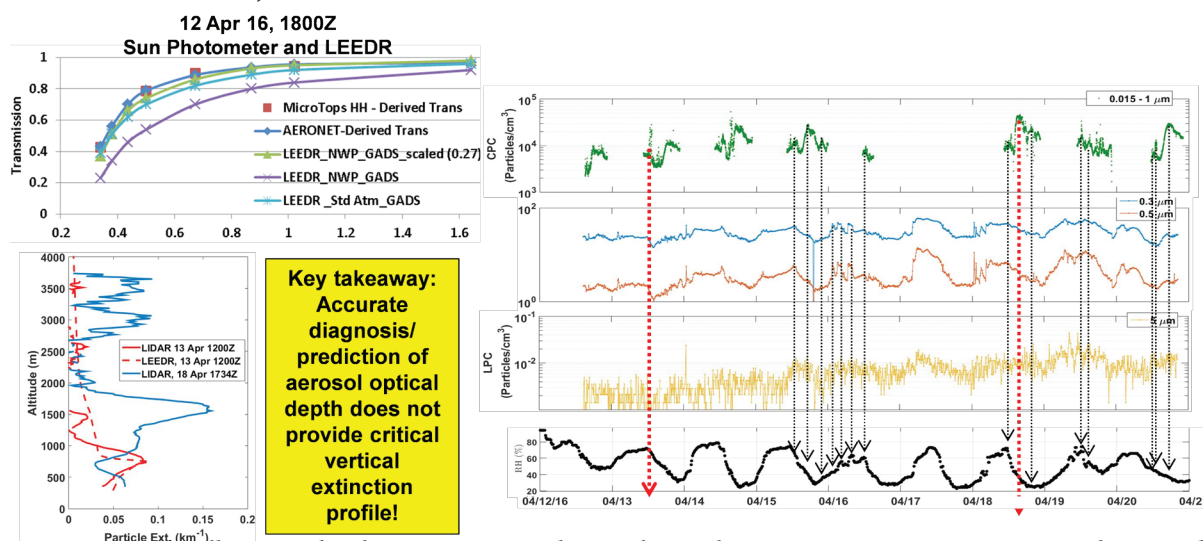


Fig. 4. Right plot illustrates the change in near-total aerosol particle counts in Dayton, OH over a 10-day period. The CPC record is non-continuous as it needs alcohol to aid in the particle counting process. The LPC's provide a continuous record, but do not provide a near-total particle number concentration. The upper left plot compares sun photometer total aerosol transmission to space to LEEDR-derived values. Lower left plot compares lidar vertical extinction (solid lines) to LEEDR values (dashed line).

# Plume Dynamics for Laser Ablated Aluminum and Titanium

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Laser-generated plume expansion is a complex phenomenon and no model currently exists to adequately describe the entire process. Simple models such as the Sedov-Taylor point blast model and the linear drag force model when applied to robust experimental observations may offer simple insights into plume expansion without requiring large computational investigations that require unknown kinetic rate inputs. Aluminum and titanium are two of the most common metals utilized in the military aeronautical industry due to their large strength to weight ratios and increased corrosion resistance properties, and thus laser effects on them are of interest to the laser lethality community.

AFIT's Department of Engineering Physics has partnered with AFRL Aerospace Systems Directorate to ablate samples with pulsed ultraviolet laser irradiation in a chamber, as seen in figure 1, in the presence of controlled buffer gases. Plasma shielding of the surface is observed and increases with increasing background pressure due to plume confinement. This results in less mass loss with increasing background pressure and an apparent increasing ablation threshold. Intensity contour images of Titanium 224 mJ ablation in 1,000 mTorr argon (broadband signal) can be seen in figure 2. At early time, the plume maintains the rectangular shape of the laser spot and expands at  $\sim 1.6$  cm/ $\mu$ s. As time progresses, the plume expands more in the z-direction than in the x-direction and begins to slow due to collisions with the background gas.

Turbulent mixing across the contact front is observed and believed to be due to Rayleigh-Taylor instability. The plume has reached a distance of 2.8 cm at  $\sim 10$   $\mu$ s. Mass loss and ablation thresholds were determined for aluminum and titanium. The highly ionized ablated plume partially shields the surface, allowing further atoms to be ablated at higher fluence but shielding the surface more at higher background pressure. Filtered fast imaging has revealed that the ion and neutral spatial distributions are different at early times, but are equal at times  $> 500$  ns.

Further experimental studies need to be conducted to determine the precise location of contact front – shock front breakaway. Work is currently being performed to analyze the particle velocity distributions and the contact front thickness and instabilities.

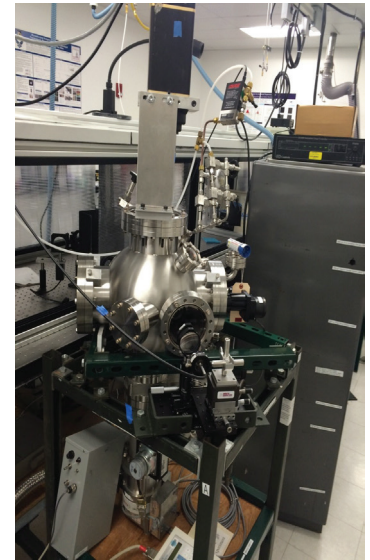


Fig. 1. Pulsed laser ablation chamber

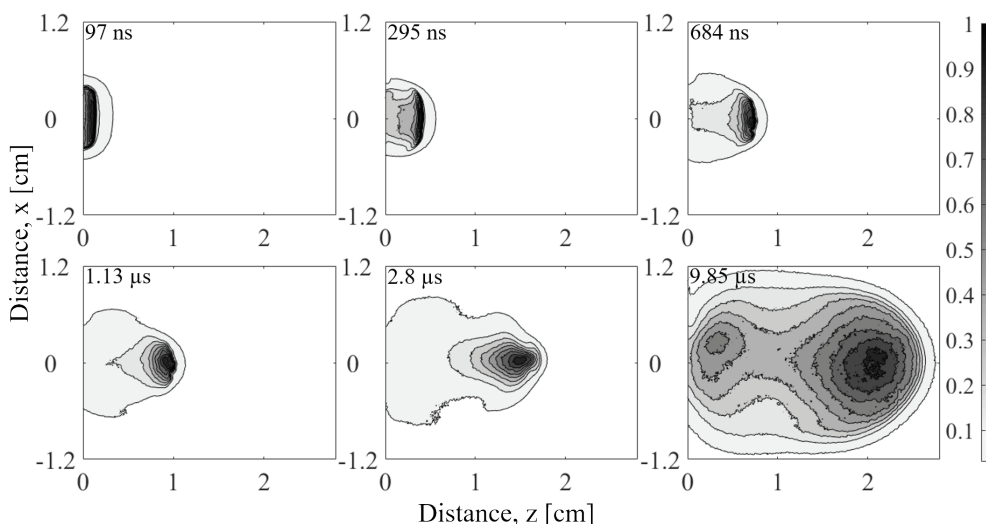


Fig. 2. Plume dynamics from titanium ablation over time

## OSD Scientific Test & Analysis Techniques Center of Excellence Celebrates 5 years and Promising Future

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The Scientific Test and Analysis Techniques Center of Excellence (STAT COE) was established five years ago at AFIT through a formal request by the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation to the Air Education and Training Command Commander. In that time the STAT COE has made a measurable impact in the quality of information that acquisition leadership receives and the training and education of the acquisition workforce in issues related to STAT. The STAT COE was established at AFIT because of AFIT's unique technical capabilities, namely the activities in the Graduate School of Engineering and Management which included development of Science of Test and Reliability Growth short courses, leading the \$1 million multi-university Test Research Consortium, providing the Air Force with the 6 course Test & Evaluation Graduate Research Certificate, and actively taking part in the National Research Council Reliability Growth within the Department of Defense Study.

Scientific Test and Analysis Techniques (STAT) are the scientific and statistical methods and processes used to enable the development of efficient, rigorous test strategies that will yield defensible results. STAT encompasses such techniques as design of experiments, observational studies, reliability growth, survey design, and software test coverage determination within a larger decision support framework. The suitability of each method is determined by the specific objectives of the test to assist acquisition leadership to understand and quantify technical risk. Over the past five years the STAT COE has worked tirelessly to advance these methods and processes from a capability, workforce development, and research perspective across the Department of Defense.

The STAT COE has contributed to advancing STAT capability, methods, and processes by working with many other organizations in academia and government. The STAT COE began with five STAT Experts supporting and mentoring 20 Major Acquisition Defense Programs on the use of STAT



The STAT COE Team

and has steadily grown to 9 STAT Experts supporting 42 programs. Working with and for Major Defense Acquisition Programs (MDAPs), STAT Experts in the STAT COE have developed a relevant collection of over 35 best practices which have grown in stature as illustrated by their extensive use, averaging over one thousand downloads per month from acquisition centers. These best practices cover STAT techniques and challenges of testing autonomous systems. Additionally, a steady stream of topic-specific short courses are requested by acquisition organizations on a reimbursable basis. In a recent call for information from STAT COE supported programs, 7 programs indicated a direct cost savings of over \$154 million attributable directly to more efficiencies and effectiveness from using STAT.

The Director for Operational Test and Evaluation, while not directly involved in funding the STAT COE, has commented on its effectiveness in the last five reports to Congress. Most recently, he noted that:

The STAT COE provides program managers with the scientific and statistical expertise to plan efficient tests that ensure the programs obtain valuable information from the test program. "Since 2012 when the STAT COE was formed, I have noted that programs

## **OSD Scientific Test & Analysis Techniques Center of Excellence Celebrates 5 years and Promising Future *Continued***

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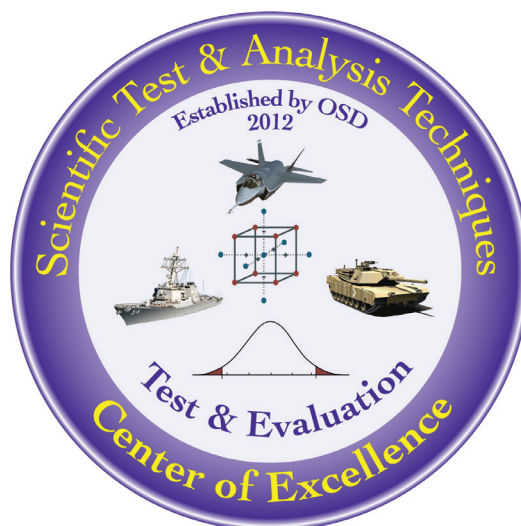
who engage with the STAT CEO early have better structured test programs that will provide valuable information., Stated Dr. Ahner. The STAT COE has provided these programs with direct access to experts in test science methods, which would otherwise be unavailable.

This support across developmental and operational testing has allowed the STAT COE to influence policy resulting in its inclusion in Department of Defense Instruction 5000.02, Operation of the Defense Acquisition System. DoDi 5000.02 directs for developmental testing, “Use scientific test and analysis techniques to design an effective and efficient test program that will produce the required data to characterize system behavior across an appropriately selected set of factors and conditions” and for operational testing “Scientific test and analysis techniques (also referred to as Design of Experiments methodologies) should be employed to design an effective and efficient T&E program.”

Recent STAT COE initiatives in the last year have included support to the F-35 program to develop the test strategy to characterize physiological episodes, leading the Navy automated software testing advancement, support to the AFRL sensors directorate test campaign plan, developing methods and processes for autonomous testing, and funding from the Department of Homeland Security for acquisition

program support. Additionally, faculty from four departments in the Graduate School are funded from these and other efforts with a total of fifteen faculty members currently associated with the STAT COE.

The Office of Secretary of Defense has provided assurance of continued baseline funding for the Center and indicated an expanded role of the STAT COE supporting technology demonstrations and experimentation campaigns as the new office of the Undersecretary of Defense for Research and Engineering is established. The STAT COE continues to support leadership in their understanding and quantifying of technical maturity during development of new technology and capabilities. Along with partnering with the Department of Homeland Security and conduct of other support and research initiatives, the STAT COE looks forward to a fruitful and expanding second five years that effectively fosters and assesses technological innovation, agility, and quality with the acquisition process; that conducts leading edge research in collaboration with AFIT’s faculty members; and that provides workforce development resources by way of shareable best practices and topic-specific STAT short courses.



## Automated Software Testing in the DoD – Current Practices and Opportunities for Improvement

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The concept of automating the testing of software intensive systems has been around for decades, but the practice of automating testing is scarce in many industries, and especially in the government defense sector. A one-year project initiated by the OSD Scientific Test and Analysis Techniques Center of Excellence (STAT COE) and sponsored by Navy OPNAV N94 set out to 1) study the degree to which the DoD has adopted automated software testing (AST), 2) share the best software practices used by industry, 3) develop and distribute an AST implementation guide intended for program management and novice DoD software test automators and 4) advance metrics that measure software test coverage. The first three of these products are available at <https://www.afit.edu/stat/>.

The research effort involved multiple people including AFIT faculty members, STAT COE staff, Arizona State University faculty members, and professionals from across the Air Force and Department of Defense acquisition community.

The first document detailing the current state of AST in the Department focused on capturing the keys to successful DoD software test automation, collecting and sharing case studies from early test automation adopters, and providing insights along with recommended strategies. The overarching finding was the difficult balance for leadership in dealing with the cultural and technical challenges to ensure software test automation programs result in a positive return on investment (ROI). The focus on test automation ROI for this potentially disruptive technological program must consider budget impacts, manpower required, automation tool familiarization time, and both the net test time savings and associated increase in test coverage of capabilities of the software under test. Some valuable lessons learned were:

- Realize the importance to not rely solely on the brittle record/playback AST tools
- Understand the automation process needs to be treated as a software development effort
- Ensure the automation project is staffed with software developers familiar with Java, HTML, xml, etc.
- Consider the test scripts need to be well

thought out in design and require many iterations before production

- Account for the script and automation framework maintenance need to be planned and budgeted for ahead of time
- Recognize that regression testing and other repetitive tests offer the best candidates for high ROI from automation.

The AFIT team focused on documenting themes, findings and automation activities common to all the services. Then each service is detailed including specific programs, organizations and service-unique practices. Specific areas addressed in the document are a) policy and guidance, b) AST initiatives, c) culture for AST, d) notable programs applying AST, e) centers of excellence, f) AST tools experience, and g) AST metrics and coverage. Although there is some overlap across these topics and within programs applying automation, these general areas can be used to tell the story of automation within and across services of the DoD.

The second document from the study, AST Practices and Pitfalls Guide, details the current best practices along with challenges as industry adapts these game-changing test methods. Clearly, companies producing massive software solutions (Microsoft, Google, Apple) have been successfully automating much of their software testing, especially early in the development at the unit level. The DoD faces the challenge that much of the early testing is done by the defense contractor and by the time software intensive systems are handed over to the military, the testing is primarily integration, functional and performance driven, and primarily front-end, black box testing. The STAT COE spent about 6 months researching and interviewing acquisition program civil service and contractor professionals implementing AST or considering using automation for at least a portion of their testing.

The review of industry highlights the incentives driving AST - incentives that do not always apply to DoD concerns. However, the investments and struggles of AST in industry provide a good vignette for the DoD community to observe and leverage its efforts as it

# Automated Software Testing in the DoD – Current Practices and Opportunities for Improvement *Continued*

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embarks on injecting more automation into software testing.

The third document, AST Implementation Guide, is more on the operational and tactical level intended to serve those in the DoD interested in applying automation to software testing. It applies a systems engineering process based on the scientific method for the steps to conduct and to achieve an automation capability along with the important need to perform a return on investment (ROI) analysis to make the business case for automation.

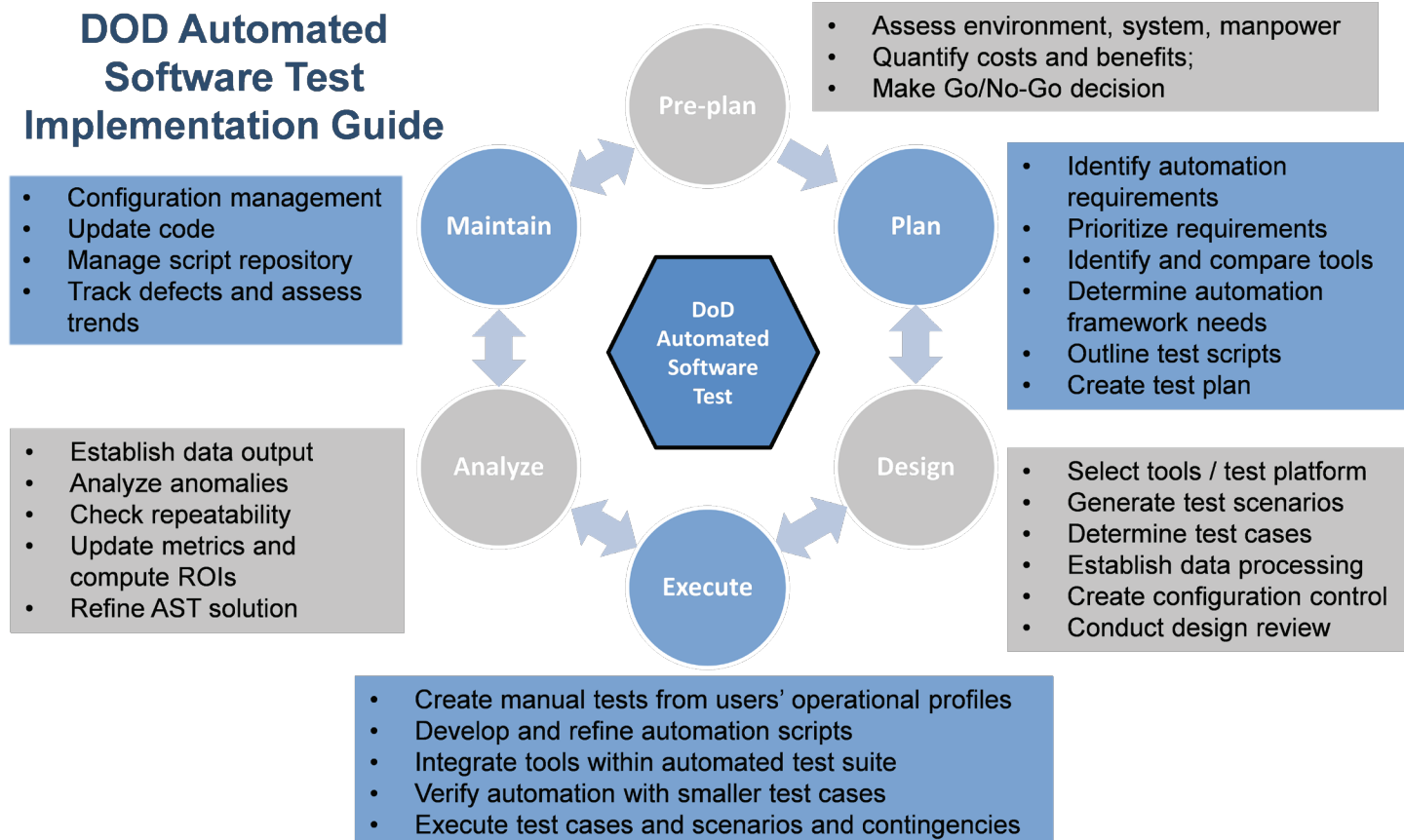
The document is organized around the phases of implementation listed below and shown in the figure, which are intended to encompass the life cycle of automated software testing within an organization's test program. Each phase has specific tasks, metrics, and deliverables that are explained in detail.

- Pre-plan – research, invest time, and gather information for making an informed decision on automation. Perform a cost benefit analysis and compute an ROI, and be sure to include

any long-term benefits, then decide whether or not to automate. Specific steps include research into the program test plan, automation capabilities and opportunities, knowing manpower skill set and resource needs, and quantifying costs and benefits from automation.

- Plan – develop an automated software test plan by identifying and prioritizing test requirements, identifying and assessing appropriate automation tools with quantifiable and discernible metrics, identifying barriers to automation implementation, drafting the test automation framework, and outlining the test script needs.
- Design – take the automation plan another level deeper in detail and make decisions for how best to execute automation. In this phase, automation tools are selected and made available, test scenarios for automation are generated, test cases are determined, the

## DOD Automated Software Test Implementation Guide



output analysis strategy is designed, and configuration control is established, all culminating in a design review.

- Execute – the activities and decisions that enables a test, otherwise to be conducted manually, to be automated. It often starts by interviewing a system operator or capturing the manual tester's steps, then decide the best automated test environment, integrate the tools within the designed test framework, develop and refine the automation scripts, and iteratively test out the execution while refining the process.
- Analyze – the focus is on the output of each automated test, typically involving recording data files or log files. The purpose is to combine, manipulate, and analyze the output data to learn output errors and faults associated with the system under test (SUT) to include integration issues. Individual steps include setting the data format, assessing the output data, ensuring anomalies are real and characterizing anomalies, revising automation metrics, and ROI.
- Maintain – this final phase is often the most time consuming and painful aspect of automation. Once test scripts have been written, executed, and refined for optimal use, something (SUT, the test environment including monitors or operating system versions and IT patches, automation tool version, etc.) changes. The scripts now fail to execute properly unless revised, which is one of the tasks in the maintenance phase.

Although the phases can be visualized and enacted in a chronological or linear fashion, we realize and stress that there is significant connectivity between them such that moving in a less structured or iterative direction can be advisable. The suggested approach also involves maturing several important automation tasks across multiple phases.

For example, automation tool selection is often considered a primary and critical decision. The implementation guide suggests tool selection and tool acquisition be a part of each of the plan, design, and execute phases, where increased knowledge and topic maturity is obtained in subsequent phases. Iteration and looping of the phases is a key to success.

Feedback on these documents has been favorable as they've been briefed to the Naval Automated Test and Analysis executive board, conferences (DoD/NASA Knowledge Exchange Conference, ITEA, MORSS, IEEE Software Technology Conference), and stakeholder organizations across DoD. The overall project is entering a second phase in FY18 that will enhance these deliverables, create a repository for AST tools and scripts, and continue direct program support to some Navy organizations at various stages in their automated software testing journeys.

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# DEVELOPING THE NEXT GENERATION

## AFRL, AFIT Help Community College Students Gain Real World STEM Experience Through SUCCESS Project

*Originally Posted Tuesday, June 27, 2017*

The Air Force Research Laboratory's Students from Community College Gaining Skills and Experience in STEM, or SUCCESS program as it's known, is designed as a vehicle to introduce community college students to AFRL and the larger Air Force to gain real world science, technology, engineering and math experience.

Community colleges serve close to half of the undergraduate students in the United States and are the gateway to postsecondary education for many minority, low income, and first-generation postsecondary education students, according to the American



AFIT faculty member Dr. David Jacques (center), with SUCCESS Program interns John Wintersohle, Jamie Workman, Morgan Oldham, Evan Lynd, and Caitlin Jenkins. (Courtesy photo)

### Association of Community Colleges

"Most recruiters are focused on bigger name schools and target students who already have experience in STEM. This program focuses on an often neglected population of students - those attending community college. Through SUCCESS, we bring community college students into AFRL as interns to gain the needed experience to be more competitive when permanent positions are available," said Dr. Mark Derriso, SUCCESS program manager.

During the year long program, students receive



During a lab session, SUCCESS Program interns collect data on different motor propulsion test combinations.

(Courtesy photo)

a salary and tuition assistance. At the end of their time, their government supervisor can take over the funding requirements and potentially hire the student into a full-time position.

"Even if the student doesn't transition to a permanent position within AFRL, they have gained a wealth of experience to complement their education and have made connections with other professionals in their career field," said Derriso.

Currently there are five students in the SUCCESS program who work in AFRL's Sensors Directorate, Airman Systems Directorate, and the Aerospace Systems Directorate. To build a connection with the other students in the program, a joint project was introduced this year where the students work with each other to solve a real world problem. AFRL teamed with AFIT on the joint project which involves a system level design, build, and flight test of an Unmanned Aircraft System, or UAS, to include the air vehicle and associated pay loads, a ground station computer, and communication between the ground and air components. Dr. David Jacques, Professor of Systems Engineering within AFIT's Graduate School of Engineering and Management, is working with the students to teach them UAS fundamentals and how to safely conduct flight tests with UAS.

The challenge project is to find a lost hiker,

maintain visual contact, and deliver medical supplies or "a communication device to them. The students have to provide surveillance of a target and keep it in the field of view of the camera and then they have to be able to deliver a quarter pound payload. They receive a



During a lab session, SUCCESS Program interns collect data on different motor propulsion test combinations. (Courtesy photo)

CONOPS for the project that lays out the challenge problem. The students break it down to determine what they need on the UAS as well as the functions it must be able to perform. They take that information and develop a set of requirements and then design, build, and test in a rapid prototyping cycle," said Jacques.

The student's participate in labs where they run experiments on topics such as motor propulsion, communication and video subsystems, and telemetry. The project culminates in a flight test and evaluation scheduled for summer 2017.

John Wintersohle is a current SUCCESS Program intern working in AFRL's Sensors Directorate. After earning an associate degree from Sinclair Community College, he transferred to Wright State University where he is working on a dual major in Computer Science and Computer Engineering.

Wintersohle was attracted to the SUCCESS Program because of the direct work experience he would gain. "Any student who wants to get a job needs to be able to show that they can apply their knowledge," Wintersohle said. "Sometimes learning to apply the knowledge is as big of a challenge as learning the material itself. The SUCCESS program, and my time with Dr. Jacques, allows me the opportunity to apply what I already know, and learn more about what I don't, to actively solve problems. This program helps me develop myself academically and professionally. I really enjoy my time here and working with the other

students." Participating in STEM outreach activities is a top priority for AFIT, and Jacques has been very involved with outreach efforts for many years.

"Coordinating UAS design projects is an area that we have a lot of experience in and I was happy to help with this project when our partners at AFRL contacted me. The students in the program have great enthusiasm and energy for the topic. I enjoy it. I think it is important to get students interested in engineering projects by hopefully making them fun, but also teaching them about interdisciplinary design - the fact that it isn't all electrical, computer, or aeronautical engineering. It tends to be a mix of all of the above in order to make a system work," said Jacques.

Jacques' focus on interdisciplinary team work has impacted the interns. Jaime Workman, an electrical engineering student at Wright State University commented that "this project has shown me that there is a lot of cross-disciplinary work to get a project done." Morgan Oldham, a student at Wright State University studying biomedical engineering, echoed Workman's thought saying "In this program I have learned that no matter what type of engineering you are studying, the material learned in class can be applied across multiple engineering projects."

The interns are applying their new knowledge to school and work projects. Caitlin Jenkins, a mechanical engineering student at the University of Dayton, has



AFIT faculty member Dr. David Jacques mentors SUCCESS Program intern John Wintersohle. (Courtesy photo)

learned about the process of designing, building, and testing and is confident this knowledge will be beneficial to her in her career.

Evan Lynd is a student at Wright State University studying computer engineering and is working at AFRL's Sensors Directorate. Working at AFRL through the SUCCESS program has opened Lynd's eyes to all of the opportunities for a computer engineer. "I have always heard that Wright-Patt is the leader in technological advancement and this is where I want to be in my career. My goal right now is to learn as much as I can," said Evan.

## AFIT's Center for Operational Analysis' Aerospace and Defense Scholar Development Program

*Originally Posted Tuesday, August 29, 2017*



Pictured left to right: Ms. Aphrodites Donald (KBR Wyle), Mr. Mark Pride (KBR Wyle), Ms. Leigh Method, SES (HAF F-35 Integration Office), Ms. Jessica Smith (The Perduco Group), Mr. Zachary Shannon (WSU), Mr. Matt Mangen (ONU), Mr. Jordan Frye (WSU), Dr. Paul Hartman (AFIT/COA)

The Air Force Institute of Technology's (AFIT) Center for Operational Analysis (COA), directed by Dr. Paul Hartman, experienced great success in its second year executing the Aerospace and Defense Scholar Development Program (A&D SDP).

A&D SDP is a program sponsored by AFIT's COA and participating industry partners, uniquely designed for undergraduate and graduate students to gain exposure to the vast array of critical operations within the aerospace and defense sector, while utilizing and growing their existing analytical and technical skills. Due to AFIT's unique mission of "education, research, and consultation," the COA's program is strategically positioned to bridge the knowledge gap between civilian students and the aerospace and defense sector regarding the multidisciplinary support efforts required in day-to-day operations. A&D SDP also strategically aligns participants for future collaboration with industry partners, providing scholars the opportunity to achieve continuing education goals within AFIT.

The Aerospace and Defense Scholar Development Program has two major components. The first component involves exposing scholars to Senior Leaders within the United States Air Force and

Executive-level Industry Partners through a combination of formal and informal briefings, meetings, and tours. A&D SDP's second focus is to afford scholars the opportunity to learn and perform structured data collection and analysis methods.

Scholars involved in this year's program visited numerous centers and program management offices within Wright-Patterson AFB to gain knowledge of their capabilities and current projects. Trips included, but were not limited to, the 711th Human Performance Wing, the Autonomy and Navigation Technology (ANT) Center, and the Center for Technical Intelligence Studies and Research (CTISR). Participants also had the privilege of attending and participating in multiple presentations from guest speakers at the Air Force Materiel Command (AFMC) Enterprise Logistics Executive Capstone Course including representatives from AFMC/A4, Air Force Safety Center, Defense Logistics Agency, General Services Administration, and Program Element Office Mobility Programs, further introducing scholars to facilities and topics of interest within the Department of Defense.

One particular highlight of the 2017 A&D SDP was traveling to Washington, D.C., to meet with Senior Leaders in the HAF/A9 and tour the Pentagon. Scholar Matthew Mangen commented, "It was an amazing experience to be able to see the inside of the Pentagon and meet with Mr. Kevin Williams. Being able to sit with a senior leader and learn about some of the day-to-day operations that take place inside the building was such a privilege."



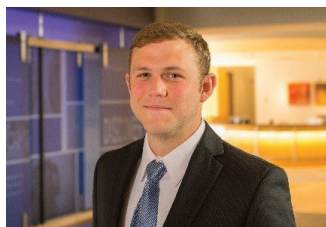
Aerospace and Defense Scholar Development Program participants Jordan Frye, Matthew Mangen, and Zachary Shannon during a trip to Washington D.C. to visit the Pentagon and meet with Senior DoD Leaders

Civilian entities that participated in the A&D SDP included original equipment manufacturers (OEMs) such as Booze-Allen Hamilton and Pratt & Whitney. Scholars also visited USAF industry partners IBM, KBR Wyle, SEGUE Technologies, and Yaskawa Motoman. When asked what he thought about this aspect of the program, scholar Jordan Frye said, “Being able to meet some of our industry partners gave us a great perspective into what kind of work they do for the military and showcase some of their specialized skills.”

The second component of the A&D SDP, structured data collection and analysis, was addressed through specific research projects the scholars selected from the COA's core focus areas: Harnessing the Power of Data, Improving Decision Cycle Times, and Reducing the Cost of Readiness. Scholars selected projects of interest to them and were assigned AFIT faculty advisors to assist them with their research efforts. Additionally, participants received in-depth education and training on AFIT's research tools and public DoD databases.

Data was collected through classic literature review techniques, as well as via semi-structured interviews with subject matter experts. Upon completion of the project, scholars presented findings and lessons-learned to the Director of the COA as well as their academic advisors, industry partner representatives, and a senior leader representative from HAF/IO. “This experience has provided an opportunity to gain a fundamental understanding of graduate level research all the while giving us exposure to high level problems the COA, AFIT, Industry partners, and the Air Force face on a daily basis,” said scholar Zachary Shannon.

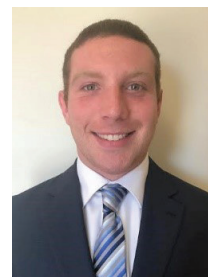
AFIT looks forward to continuing the A&D SDP next year. Program coordinator and A&D SDP graduate, Jessica Smith, has been working with current graduate-level scholars George Diehl and Chris Krolikowski to further formalize and strengthen the program. Jessica will graduate with her master's degree from AFIT in Logistics and Supply Chain Management in September of 2017 and will continue her education at AFIT as a PhD student in the Logistics and Supply Chain Management Program. “As the first graduate of the program, it is amazing to see how much the A&D SDP has grown. The educational and professional benefits the program provides, paired with the synergistic combination of DoD and industry partner involvement, is invaluable to participants in all stages of their academic careers.”



This year's scholars included: Jordan Frye, Wright State University – Jordan is a Supply Chain Management major and will be graduating with his bachelor's degree in the spring of 2018. He

has experience in Operations Coordination and is interested in 3-D Printing and Directed Energy within the defense sector. Upon graduation, Jordan intends to apply to AFIT's master's degree program in Logistics and Supply Chain Management.

Matthew Mangen, Ohio Northern University – Matthew, a second year participant of the A&D SPD, is a Business Management major with minors in Business Analytics and Entrepreneurship. In the winter of 2017 he will graduate with his bachelor's degree and is looking

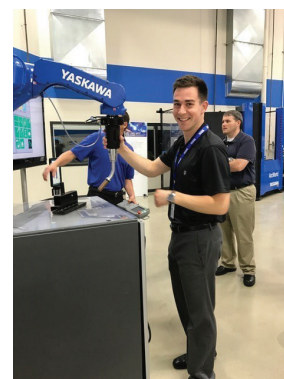


forward to applying to AFIT's Operations Research master's degree program. Specific interests of Matt's include the Industrial Internet of Things and Predictive Maintenance.



Zachary Shannon, Wright State University – Zachary is a Finance major, pursuing a Bachelor of Science in Business. He is a member of the USAF Air National Guard and has experience with tier two IT operations and meeting accounting compliance deadlines. When he graduates, he

plans to work towards obtaining his Certified Financial Planner (CFP) License and enroll in the Cost Analysis master's degree program at AFIT.



Zachary Shannon, Aerospace and Defense Scholar Development Program participant during a visit to Yaskawa Motoman, a robotics company headquartered in Dayton, Ohio.

## Center for Cyber Space Research: Advanced Cyber Education Program (ACE)

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The Center for Cyberspace Research (CCR) at AFIT offers the Advanced Cyber Education (ACE) Program to Academy and ROTC cadets between their junior and senior years in college who are majoring in computer science, computer engineering or electrical engineering.

The ACE program is a four-week course that takes place at the Air Force Institute of Technology (AFIT). The program consists of an instructional component, cyber war exercises, and cyber officer development days that focus on the study of cyber and its unique leadership challenges.

The original ACE cyber security boot camp was founded by the Air Force Research Laboratory (AFRL) in Rome, New York. ACE commenced in the summer of 2003 and the first year's graduates included 17 students from across the nation. In 2011, the ROTC portion of AFRL's ACE program moved to AFIT where it continues to develop the next generation of cybersecurity leaders through an intense program that immerses students in the cybersecurity discipline while educating them on becoming future military leaders.

Although the ROTC ACE program was canceled in 2013-14 due to sequestration and budget issues, it has rebounded. The 2017 class had joint participation

from 20 Air Force students, 20 Army students and 1 Air National Guard student. The program covers a wide variety of topics in cybersecurity and mission assurance. The course is a key element in developing critical thinkers and technical leaders who can solve real-world problems in the area of cybersecurity. ACE cadets leave AFIT understanding that cyber dominance and multi-domain operations are prerequisites for superiority in Land, Sea, Air, Space and now Cyberspace.



ACE Students in the CCR Lab



2017 ACE Graduates



## AFIT Offers New Program to Support the Systems Engineering Acquisition Workforce

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In October 2016, the Department of Systems Engineering and Management at the Air Force Institute of Technology began offering a new program to support the systems engineering acquisition workforce.

The new systems engineering certification program and a modified systems engineering master's program focuses on delivering quality and timely education to Air Force civilians and military. The AFIT Graduate Systems Engineering Program has been in existence and Accreditation Board for Engineering and Technology (ABET) accredited since 1974 and is one of the oldest systems engineering masters programs accredited in the United States.

Since 2003, AFIT has graduated more than 500 systems engineering students and has created a variety of programs. Graduate systems engineering programs include resident thesis-based graduate systems engineering masters (18 months, full time), online version of systems engineering masters (one course/quarter, 12 quarters) and online Masters of Engineering in Applied Systems Engineering which is a non-thesis program that includes a capstone (one course/quarter, 12 quarters).

The new program arose from the actions of the AFIT Systems Engineering Research and Analysis Group who conducted an outreach campaign to the Air Force Materiel Command, Air Force Life Cycle Management Center, Space and Missile Systems Center Engineering Directorate, Assistant Secretary of the Air Force Acquisition, Technology and Logistics and the Assistant Secretary of the Air Force Science and Technology and Engineering to better understand systems engineering educational needs. Discussions with the stakeholders revealed that a systems engineering certification would provide the ability to credential key engineers who are charged with overseeing major programs. More than 2,000 civilian engineers at the Air Force Life Cycle Management Center and the Space and Missile Systems Center require systems engineering skills to do their jobs.

Nearly half of these engineers are required to be

at the highest levels of proficiency (expert or advanced) in their field.

The Systems Engineering Research and Analysis Group listened to stakeholders who expressed they were looking for a program that goes well beyond the systems engineering training conducted under the Defense Acquisition University and is underpinned by graduate level education and critical thinking. Dr. Kenneth Barker, USAF senior leader for Systems Engineering, AFLCMC Engineering Directorate, stated "This program is supporting the Department of Defense and Air Force imperatives to revitalize engineering excellence, to include 'Owning the Technical Baseline'."

Barker said their four-year journey into competency management has confirmed that systems engineering is the most demanded technical skill in acquisition engineering and that AFIT is doing a great job tailoring their systems engineering certification program for the Air Force's practicing systems engineers.

"There is no better one-year systems engineer educational program available where students will be equipped with skills necessary to diagnose unique Air Force acquisition systems engineering challenges and select appropriate tools and processes to mitigate risk and ensure successful outcomes," Barker said. "Systems engineer certificate holders will meet a fundamental requirement to be validated as an 'expert' meeting a fundamental requirements to hold critical engineering positions requiring expert-status in systems engineering, such as Lead Systems Engineer, Chief Engineer, and Director of Engineering. Moreover, systems engineer certificate holders will receive additional credit in all future applications for promotions."

The AFIT faculty is excited about the opportunity to help meet Air Force needs and retired Brig. Gen. (Dr.) Kenneth Moran, Director of the AFIT Systems Engineering Research and Analysis Group, said that AFIT is motivated to help give engineers the skills and competencies they need to do a very complex job and committed to the maximum flexibility possible.

## **AFIT Offers New Program to Support the Systems Engineering Acquisition Workforce** *Continued*

Dr. John Colombi, Associate Professor of Systems Engineering and Chair of the Systems Engineering program, said stakeholders wanted students taking the certificate program to have the ability to finish within 12 months as well as have options for accelerated completion, provide the ability to complete the certificate in residence as well as via distance learning during non-core duty hours, and provide those interested with an option to follow-on and complete a master's degree. Colombi said they have revised their certificate program to meet these needs.

"We continue to adapt to meet the educational needs of the Air Force," Dr. Michael R. Grimaila, AFIT Professor and Department Head of Systems Engineering and Management, said. "The new certificate program is one example that provides the ability for civilian and military engineers to bring relevant problems from their office into an academic setting so they can apply what they have learned to help solve the problem. This creates a synergistic environment that rarely exists

where fellow students can contribute to solving real world defense focused problems."

In the summer of 2016, the Assistant Secretary of the Air Force Acquisition Career Management provided funding to develop and execute the new AFIT program and the first students started their coursework in October 2016. Gail Forest, AFMC Director of Engineering and Technical Management, stated "The initial cohort of students recently completed its first course and the informal feedback received is positive. We continue to target key engineers charged with overseeing systems engineering and the potential for assuming higher levels of systems engineering responsibility within the engineering enterprise."

A second group of students began the program in April. For more information on the new systems engineering program, contact Dr. John Colombi at [john.colombi@afit.edu](mailto:john.colombi@afit.edu).

*Originally published May 05, 2017 on the WPAFB website*

## **Collaboration Across AFIT to Develop Cyber Resiliency Smart Workforce**

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**“The Air Force’s ability to fly, fight and win in air, space and cyberspace is threatened by increasingly competent adversaries in the cyberspace domain,”** Dennis Miller, Cyber Resiliency Office for Weapon Systems (CROWS) Director.

Recent collaboration across AFIT’s complementary set of schools, research centers, and engineering departments has led to robust response to the USAF’s increasing need for weapon system security and resiliency. As modern warfighting systems continue to increase in size and complexity, current systems security approaches are not adequately ensuring mission critical systems maintain effectiveness when operating in highly contested cyberspace environments—those including advanced cyber threats, numerous disruptions, and emergent behaviors.

Thus, a collaboration of personnel from AFIT to include the Department of Systems Engineering and Management (ENV), the Department of Electrical and Computer Engineering (ENG), the Center for Cyberspace Research (CCR), and the School of Systems and Logistics (LS) have joined under the

banner of AFIT’s own Air Force Cyber Technical Center of Excellence (AFCyTCoE) to provide a robust education and training solution to develop the necessary cyber resiliency workforce of the future.

This cyber resiliency smart workforce will be responsible for developing holistic, resiliency-focused views of advanced warfighting systems (i.e., system-of-systems) that thoroughly account for the complexities and real-time operational constraints associated with weapon systems, their supporting and enabling systems, and their dependencies across the system’s entire lifecycle.

Moreover, they will be equipped with management strategies and engineering approaches to successfully acquire, field, operate, and sustain secure and resilient systems. They will be required to demonstrate the ability to reason about system-level challenges and provide integrated, cost-effective solutions that reduce both technical and operational risk to the weapon system, acquisition program, and execution of the mission while meeting performance expectations.

# Baking-in Resiliency and Cyber-Hardening MIL-STD-1553

*Capt John Willis and Dr. Robert Mills*

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MIL-STD-1553 is a communication bus designed to provide communication across sensors, actuators, and controls within military vehicles, aircraft, ships, and satellites. However, 40+ years ago when this protocol was developed, the focus was not cyber-security, but reliability. Currently, AFIT is working with AFRL/RV, space vehicles, and AFRL/RV, sensors directorate, in hardening these systems against modern cyber-attacks.

Applying conventional cyber-defensive techniques is often not a viable option due to the inherent limitations in the technology and the real-time processing requirement of the systems. Further, adding a hardware solution, such as an intrusion detection system (IDS), after the fact is not feasible for various reasons, such as size, weight, and power concerns; physical inaccessibility; and the prohibitive cost to updating the vast Air Force inventory.

Current AFIT research is attacking this challenge with a two-step approach. First, we developed a generic architecture for a notional space vehicle and a taxonomy of attacks that could be achieved based on a systems-level analysis of the vulnerability space (Fig. 1) [1]. Viewing attacks through this paradigm highlights several potential attack vectors that conventional security approaches fail to consider, and if left undetected, these attacks could yield physical effects

limiting the satellite's long term mission or performance. Our approach also gives insight into architectural design considerations which improve the system's overall resiliency.

The second aspect of our research focuses on the ability to assure trustworthiness of devices communicating on the 1553 data bus. This research extends prior AFIT research based on Wired Signal Distinct Native Attribute (WS-DNA) and lays the groundwork toward developing an anomaly-based IDS that could aid in detecting rogue or misbehaving devices [2]. Similar to previous WS-DNA research, 1553 signal fingerprints are generated for different regions of interest in the 1553 message (Fig. 2) and used to train a machine learning classifier. Test data is then applied to determine how well the classifier can identify/authorize 1553 devices present on the bus.

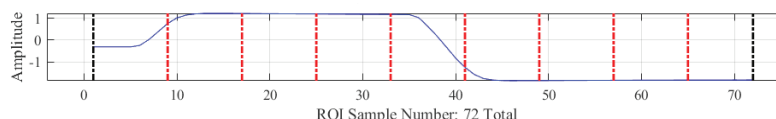


Fig.2. Analog 1553 Fingerprint Waveform

Research results indicated the WS-DNA classifier was able to detect a rogue device at a 79% rate while maintaining a true verification rate of greater than 80% (i.e., the 1553 terminal is valid). This strategy provides a viable method for protecting a legacy architecture from modern cyber threats like masquerading, exfiltration, and eavesdropping that are mostly unaccounted for in current system architectures. Further, this research demonstrates the ability to perform the fingerprinting and classification using the built-in sampling and processing capability of a commercial 1553 terminal unit. This eliminates the need for additional hardware and will accelerate the implementation of WS-DNA fingerprinting in operational use.

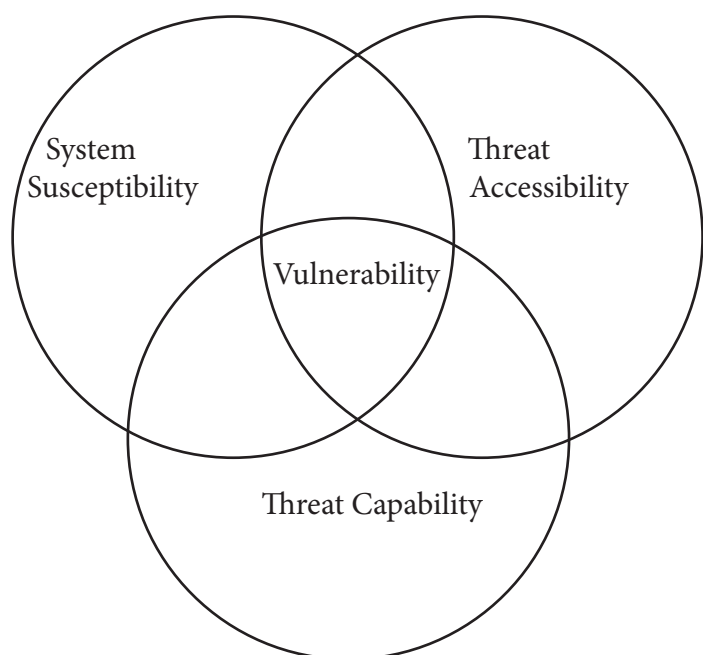


Fig. 1. System Threat Model

[1] JM Willis, RF Mills, LO Mailloux, SR. Graham. Considerations for Secure and Resilient Satellite Architectures. 2017 - International Conference on Cyber Conflict

[2] JM Willis, RF Mills, LO Mailloux, SR. Graham. MIL-STD-1553 Device Characterization using Organic Interface Functionality. 2018 - SCI-300 Symposium on Cyber Physical Security of Defense Systems

# CONGRATULATIONS GRADUATES

## AFIT Graduates New Class of Master's, Doctoral Students

*Originally Posted Friday, March 31, 2017*



AFIT's March 2017 Graduating Class

The Air Force Institute of Technology Graduate School of Engineering and Management at Wright-Patterson Air Force Base hosted a commencement ceremony at the National Museum of the United States Air Force March 23. Degrees awarded at the ceremony included 254 master's (two students earned dual degrees) and two doctor of philosophy degrees. In addition, three master's and 24 doctoral graduates returned to walk in the ceremony.

This graduating class included three Air Force non-commissioned officers, nine U.S. Army, two Marine Corps and 15 civilian students. In addition, one international officer from Argentina received a degree. More than 20 different research areas were represented.

During his speech, Dr. Todd Stewart, AFIT's Director and Chancellor, highlighted a third generation AFIT graduate - Capt Aaron Vincent, who earned a master's degree in logistics & supply chain management and was a Distinguished Graduate. His father, Roger Vincent, a retired Air Force colonel, earned a master's degree in electrical engineering in 1997. His grandfather, Oakley Vincent, a retired Air Force lieutenant colonel, earned both a bachelor's and master's degree in electrical engineering in 1965. "What a great family tradition of service to our Air Force and our country," Stewart said.

In addition, Stewart paid special tribute to some very special guests: More than 20 parents and grandparents who were veterans of the Korean, Vietnam and Gulf Wars were in attendance.

The commencement speaker was Gen. James Holmes, commander of Air Combat Command.

"The tie between the military aviation technology and the engineers and scientists that provide it has many layers. All ACC Airmen depend on you and the work that you will do...to give them an edge in combat, vital logistics support, and for their very lives," Holmes said.

"The many late nights spent studying and the time spent catching up on homework or developing your thesis...will enable each and every one of you to put your expertise to work and make a huge impact on our Air Force," he said. "I am really excited to think about what each of you will bring to the table after you leave here today.

"In my humble opinion, AFIT offers the best professional military education the Air Force has to offer. A long tradition, continuously updated, means we provide unique graduates that we can't get from any other university anywhere else," Holmes said.

In closing, Holmes charged the graduates "to continue in their duties, remember the sacrifices of those that came before us and the Airmen that we serve with today. May we all remember our obligations to the men and women that we serve with."

Since AFIT's establishment in November of 1919, the institute has counted among its alumni some of the most accomplished engineers and scientists known worldwide, both past and present. This list includes Air Force pioneers Gen. George Kenney, Gen. Jimmy Doolittle, Gen. Bernard Schriever, Gen. Benjamin Chidlaw, Astronauts Virgil "Gus" Grissom, Gordon Cooper, and Guion Bluford, to name a few.

AFIT first granted accredited resident degrees in 1955 and since then more than 18,760 master's and 795 doctoral degrees have been awarded.

To learn more AFIT, visit: [www.afit.edu](http://www.afit.edu)

## Enlisted Students Earn Advanced Degrees at AFIT

*Originally Posted Tuesday, August 29, 2017*

The Air Force Institute of Technology (AFIT), located at Wright-Patterson AFB, Ohio, is the Air Force's Graduate School of Engineering and Management as well as its institution for technical professional continuing education (PCE).

In 2002, then Secretary of the Air Force, Dr. James Roche, championed an initiative to open AFIT's Graduate School of Engineering and Management to senior enlisted personnel. Secretary Roche truly believed in the importance of the enlisted force to military achievements in science and technology. Two years later, eight Air Force and six Marine Corps senior noncommissioned officers (NCO) received master's degrees from AFIT. In 2014, MSG Jeffrey Morris, USA, became the first enlisted student to earn a PhD at AFIT. To date, more than 100 certificates, masters, and doctoral degrees have been awarded to enlisted personnel. And just recently, AFIT alum SMSgt Jason Russi was awarded a U.S. Patent for work done while a graduate student at AFIT on "Stereoscopic 3-D Presentation for Air Traffic Control Digital Displays".

The Enlisted-to-AFIT program is a unique element of enlisted professional development. In conjunction with other training and education programs, resident AFIT-sponsored science, engineering, and management graduate degree opportunities further develop Senior NCO's technical education and skills. Ultimately, this program provides enhanced combat capability for diverse career fields with positions requiring a higher degree of education.

MSgt Ronald Mitchell earned a master's degree in materials science from AFIT in 2017. He is currently working as a Project Engineer at the National Air and Space Intelligence Center at Wright-Patterson AFB, OH. MSgt Mitchell shared, "Almost immediately I began seeing the benefits of my advanced degree to the Air Force, to my career field, and with the enlisted members I was stationed with. My leadership empowered me, my senior scientists supported me, and my peers welcomed me."

MSgt Theodore Holliger, a current AFIT master's student working towards a degree in Logistics and Supply Chain Management, stated "AFIT teaches you to think critically. I don't know where my education will take me, but I do know that no matter where I go, I will be prepared to offer solutions that are



viable and defensible to leadership. In my opinion, that is where the enlisted force should be focused. Solutions brought to decision makers need to be sound - based on objective data, not on emotion or opinion. Wherever I go, I will be prepared to contribute in that manner."

Airmen interested in applying for the 18 to 24 month program must be at least a technical sergeant select with a minimum of eight years' time in service, 24 months' time on station, have completed their 7 skill-level (craftsman) upgrade, and possess a bachelor's degree from a regionally accredited college or university and a Community College of the Air Force degree. In addition to academic transcripts, applicants have to provide test scores from either the Graduate Record Examination or Graduate Management Admission Test, depending upon the specific AFIT degree-program requirements. There is a three year retainability condition upon graduation.

Personnel apply to AFIT based on the Enlisted-to-AFIT Call for Nominations sent out by AF-A1DLE in November each year and announces selections in March or April.

A component of Air University and Air Education and Training Command, AFIT is committed to providing defense-focused graduate and professional continuing education and research to sustain the technological supremacy of America's air, space, and cyber forces. AFIT accomplishes its mission through four schools: the Graduate School of Engineering and Management, the School of Systems and Logistics, the Civil Engineer School, and the School of Strategic Force Studies. Through its Civilian Institution Programs, AFIT manages the educational programs of officers enrolled in civilian universities, research centers, hospitals, and industrial organizations.

For more information, please visit [www.afit.edu](http://www.afit.edu), or email [A3PS@afit.edu](mailto:A3PS@afit.edu)

# DISTINGUISHED ALUMNI

## AFIT Alum Selected as AFRL Commander

Originally Posted Wednesday, January 4, 2017

AFIT alum, Brig Gen William Cooley (PhD, Applied Physics, 1997), was selected as the new commander, Air Force Research Laboratory, Air Force Materiel Command, Wright-Patterson Air Force Base, Ohio. Brig Gen Cooley is currently program executive, Programs and Integration, Missile Defense Agency, Redstone Arsenal, Alabama.

Gen. Cooley served in a variety of technical management, leadership and staff positions including command at the group and wing level. His assignments include Director, Global Positioning Systems (GPS) Directorate, Space and Missile Systems Center, Air Force Space Command Commander, Phillips Research Site and Materiel Wing Director, Space Vehicles Directorate, Air Force Research Laboratory System Program Director for operational command and control programs Program Manager, Air Force Distributed Common Ground System Defense Sector Program Manager, Office of Security

Cooperation -Afghanistan, Kabul Program Element Monitor for Military Satellite Communications and staff officer at the Warrior Preparation Center, Einsiedlerhof Air Station,

Germany. Gen Cooley is co-author of the book "A Guide for DoD Program Managers" with Brian C. Ruhm published by Defense Acquisition University Press in 2014.



The Dayton Daily News article may be found on at [www.DaytonDailyNews.com](http://www.DaytonDailyNews.com)

## AFIT Alum Awarded Patent

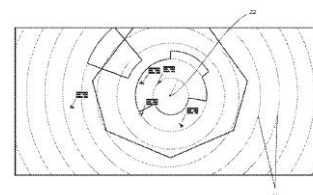
Originally Posted Monday, July 10, 2017

AFIT alum SMSgt Jason G. Russi (M.S. Information Resource Management, 2013) with AFIT faculty collaborators Dr. Brent Langhals and Dr. Michael Miller, have been awarded a patent for "Stereoscopic 3-D Presentation for Air Traffic Control Digital Displays" (U.S. Patent Number 9,667,947)

**Abstract:** An apparatus and method of presenting air traffic data to an air traffic controller are provided. Air traffic data including a two dimensional spatial location and altitude for a plurality of aircraft is received. A disparity value is determined based on the altitude for each aircraft of the plurality of aircraft. Left and right eye images are generated of the plurality of aircraft where at least one of the left and right eye images is based on the determined disparity value. The left and right eye images are simultaneously displayed to the air traffic controller on a display. The simultaneously displayed images provide an apparent three-dimensional separation of each of the aircraft of the plurality of aircraft on the display.



|                                                                                                                                                                                             |                              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (12) <b>United States Patent</b><br>Russi et al.                                                                                                                                            |                              | (10) <b>Patent No.:</b> <b>US 9,667,947 B2</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|                                                                                                                                                                                             |                              | (45) <b>Date of Patent:</b> <b>May 30, 2017</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| (54) <b>STEREOSCOPIC 3-D PRESENTATION FOR AIR TRAFFIC CONTROL DIGITAL RADAR DISPLAYS</b>                                                                                                    | (56) <b>References Cited</b> |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| (71) Applicant: <b>The United States of America, as represented by the Secretary of the Air Force, Washington, DC (US)</b>                                                                  |                              | U.S. PATENT DOCUMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| (72) Inventors: <b>Jason G Russi, Beaver Creek, OH (US); Brent T Langhals, Union, KY (US); Michael E Miller, Xenia, OH (US); Eric L Heft, Kettering, OH (US)</b>                            |                              | 5,227,786 A * 7/1993 Hancock<br>5,374,932 A * 12/1994 Wyszogrod ..... G08G 5/065 342/29                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| (73) Assignee: <b>The United States of America represented by the Secretary of the Air Force, Washington, DC (US)</b>                                                                       |                              | (Continued)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| (*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 330 days.                                                                  |                              | FOREIGN PATENT DOCUMENTS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| (21) Appl. No.: <b>14/186,040</b>                                                                                                                                                           |                              | EP 0405430 B1 4/1995<br>1458331 A1 8/2004                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| (22) Filed: <b>Feb. 21, 2014</b>                                                                                                                                                            |                              | OTHER PUBLICATIONS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| (65) <b>Prior Publication Data</b><br>US 2014/0306950 A1 Oct. 16, 2014                                                                                                                      |                              | "DFS tests 3D Air Traffic Control Workstation that uses Christie Projectors", <a href="http://www.christiedigital.com/en-us/3d-and-advanced-visualization-case-studies/3d-and-advanced-visualization-projector-installations">http://www.christiedigital.com/en-us/3d-and-advanced-visualization-case-studies/3d-and-advanced-visualization-projector-installations</a> Pages 3d-air-traffic-control-workstation.aspx.                                                                                                                                                                                                                                                                                                                                            |
| (60) Provisional application No. 61/768,573, filed on Feb. 25, 2013.                                                                                                                        |                              | (Continued)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| (51) <b>Int. Cl.</b><br><b>H04N 13/04</b> (2006.01)<br><b>G01S 13/93</b> (2006.01)<br><b>H04N 13/00</b> (2006.01)                                                                           |                              | Primary Examiner — Maurice L. McDowell, Jr.<br>(74) Attorney, Agent, or Firm — AFMC/OJAZ, Charles Figer, Jr.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| (52) <b>U.S. Cl.</b><br>CPC ..... <b>H04N 13/04</b> (2013.01); <b>G01S 13/9303</b> (2013.01); <b>H04N 13/0002</b> (2013.01); <b>H04N 13/0434</b> (2013.01); <b>H04N 2013/0001</b> (2013.01) |                              | (57) <b>ABSTRACT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| (58) <b>Field of Classification Search</b><br>CPC ..... G06T 15/00; G06T 17/20; G06T 17/00; G06T 15/10; G06T 15/00; G06T 7/0051; H04N 13/04; G02B 27/22                                     |                              | An apparatus and method of presenting air traffic data to an air traffic controller are provided. Air traffic data including a two dimensional spatial location and altitude for a plurality of aircraft is received. A disparity value is determined based on the altitude for each aircraft of the plurality of aircraft. Left and right eye images are generated of the plurality of aircraft where at least one of the left and right eye images is based on the determined disparity value. The left and right eye images are simultaneously displayed to the air traffic controller on a display. The simultaneously displayed images provide an apparent three-dimensional separation of each of the aircraft of the plurality of aircraft on the display. |
| (Continued)                                                                                                                                                                                 |                              | 20 Claims, 10 Drawing Sheets                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |



## Alumni Profile: Major Tyrone Lewis

Ms. Kathleen Scott

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937-255-3636 x4393

Major Tyrone Lewis enlisted in the Army in 1996 as a cable systems maintainer. He made Staff Sergeant in 48 months – the fastest time allowed by law – while going to night school to earn his bachelor's degree. At the recommendation of a mentor, Lewis completed Officer Candidate School and was commissioned as a Second Lieutenant in 2002. He earned his bachelor's degree in management studies from the University of Maryland in 2004.

MAJ Lewis was involved in the Army's initial planning for addressing the emerging cyber workforce challenges which later gave rise to the Army Cyber Command. "I was the boots on the ground going to the 12 organizations that the National Security Administration had designated Centers of Excellence for Cyber and ended up coming to AFIT," said Lewis.

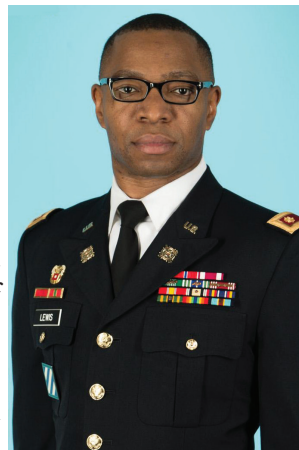
While at AFIT, Lewis completed the Cyber 300 course where he learned to apply cyber tools and concepts at an operational and strategic level. As a result of that training, Lewis coordinated a Memorandum of Agreement between the Army and AFIT to bring 7 Army students to AFIT each year for a cyber master's degrees. Major Lewis was part of the first group of Army officers to attend AFIT under the new agreement. He graduated in 2014 and then remained at AFIT to earn his doctorate in Computer Science with an emphasis on cyber operations. While working towards his doctorate, Lewis faced two serious family issues – the death of his younger brother and the birth of his son who was diagnosed with kidney issues. Quitting the program never occurred to MAJ Lewis. Not only did he push through after these events, he used them to focus his research.

For his dissertation, Lewis looked at the problem of how to detect rogue satellites as friendly or foe. Inspired by biological DNA plots, Lewis created an innovative integrated trust management system that used both application-layer and physical-layer markers to authenticate users and their communication sources using an approach adapted from the medical disease diagnostic testing community. "I took the inspiration from biology. We can look at a DNA plot and identify the things that are distinct to an individual and compare those to someone else to see dissimilarities. The challenge is - do we have enough microscopic power, or sensitivity, to detect

such minute differences when we are looking at satellite transmissions," said Lewis.

In this adapted approach, trust markers of byzantine behavior are employed to detect deviation from normal, where abnormal radio frequency (RF) traffic patterns are labeled infectious electronic network-diseases (eNDs). Trust management enabled devices consider diagnostic evidence of logical and pathological RF-DNA markers to predict and mitigate eNDs. Major Lewis' end-to-end RF network prototype improves upon origin identification accuracy using either physical-layer or application-layer techniques in isolation. "This system helps operators to guard against compromised systems, insider threats, and adversarial radio transmissions using a greater combination of tell-tale factors than those available in the past," said Dr. Kenneth Hopkinson, Professor and Interim Head in the Department of Electrical and Computer Engineering and Lewis' doctoral advisor.

Major Lewis is currently working at the Army Cyber Command in Fort Belvoir, Virginia as the Technical Lead, Office of Primary Responsibility & Executive Agent for Cyber Training Ranges. He is married to an Air Force officer and has four children. He comes from a family where many have served in the military, but he is only the second to become an officer. He earned a Bronze Star for his engineering efforts while deployed with the 3rd Infantry Division to Camp Victory in Baghdad as a Junior Network Engineer where he designed fiber optic networks and maintained the communications infrastructure. MAJ Lewis credits mentors and leaders who recognized his abilities and pushed him to move forward, stating: "Mentors have been great for me throughout my military career. If I didn't have them sitting back and watching I definitely wouldn't be where I am now. It takes mentors and leaders who believe in you to give you the opportunity to excel."



# IN MEMORIAM

## Dr. Shankar Mall

**Former Aeronautics and Astronautics Department Head & AFIT Professor**



**D**r. Shankar Mall passed away on September 27, 2017 at KMC after a long standing illness. He is survived by his wife Raj, son Sharal, daughter in law Sunita and grandsons Nikhil and Rithik. He was a very devoted husband, loving father, caring grandfather and father-in-law. Not only

was he a very determined and lively individual but also a selfless soul who always placed his family first. He was idealistic and sincere in his thoughts and actions. He will forever be an inspiration to his family, friends and colleagues. His cherished memories live on in our hearts & souls and his attributes in his son and grandsons.

Professionally, Dr. Mall had more than 30

years of teaching and research experience, and he had served as Head of the Aeronautics and Astronautics Department at the Air Force Institute of Technology (AFIT) from 1990-98; Principal Materials Research Engineer from 1998-2003 at the Air Force Research Laboratory (AFRL) Materials and Manufacturing Directorate; and also as AFRL Professor at AFIT from 1998-2003. More than 100 master's and Ph.D. level students and 15 post-doctoral associates have worked with him. He was a fellow of ASME and an associate fellow of AIAA. He had served as associate editor of the Journal of Engineering Materials and Technology, Experimental Mechanics, and the Journal of Composites Technology and Research. He was also a member of the advisory board of the Key Engineering Materials Series. He has been published in more than 250 archival journal papers. He was recognized as an AFIT Distinguished Professor. His presence at AFIT will be deeply missed.

## Dr. Delmar Wallace “DW” Breuer

**Former Professor and Department Head**

**D**r. Delmar Wallace “DW” Breuer, of Centerville, formerly of Kettering, Ohio passed away on October 13, 2017 at the age of 92. He was preceded in death by his wife of 59 years, Ethelene (Paschal) Breuer; parents, two sisters, and five brothers. Surviving are his two daughters, four grandchildren, six great grandchildren, and his sister.

DW was born in rural St. James, Mo. on June 21, 1925. He attended grade school in a one-room school house, and graduated from St. James High School, earned a BS in Aeronautical Engineering at Iowa State, MS in Structures at the Missouri School of Mines, Ph.D. in Aeronautical and Astronautical Engineering at Ohio State, and served in the Navy from 1943 to 1946. His four brothers also served in the military. He met Ethelene while teaching at MSM. They married July 31, 1949. DW's first position following college was as Instructor of Engineering Mechanics at Missouri School of Mines.

In 1950, he was hired by North American Aviation and relocated to Los Angeles. In 1951, he was hired by the Air Force Institute of Technology, where he worked for the next 30 years. DW became a Department Head in 1958. He retired as Professor Emeritus of Aerospace Engineering on Jan 1, 1981.

DW enjoyed many activities including golf, ping-pong, bridge, fishing, and coaching a ladies softball team. He was a member of Christ United Methodist Church since 1952, where he taught classes and served as chair and member of many committees. He was a tutor at Wesley Center and a mobile meals deliverer for many years. He also appreciated the special friendship of Jane Jancauskas.



## Dr. Ray Sturgis Booth

### Former Professor of Physics

Booth, Ray Sturgis, 79, a loving and devoted husband, father, and grandfather, passed away suddenly at home on Sunday, October 15, 2017. Born in Miami, Florida, Ray and his family later moved to Homestead, Florida, where he earned recognition as a national merit scholar, an all-conference basketball player, and a participant in track competitions at the state level representing South Dade High School. His continuing education at the University of Florida included a bachelor of electrical engineering, a master of science in nuclear engineering, and a Ph.D. in nuclear engineering.

Upon completing his education, Ray served for three years in the United States Air Force as an instructor of physics at the Air Force Institute of Technology, Wright-Patterson Air Force Base, in Ohio. After his honorable discharge in 1968 with the rank of captain, he became employed at Oak Ridge National Laboratory (ORNL) where he served in various research, management, and engineering positions until his retirement in 1997.

Ray's research accomplishments included over 80 publications mostly in the areas of basic physics, environmental modeling, and modeling and control of nuclear systems, with the last being published in 2017. He was on special assignment to the Clinch River Breeder Reactor Project Office from June 1981 to October 1983 directing instrumentation and licensing activities. In 1984 he was elected a Fellow in the American Nuclear Society. His highest positions as

manager at ORNL were Section Head in the Instrumentation and Controls Division and Manager of the ORNL Light Water Reactor and Liquid Metal Reactor

Research Programs Specialists under his management monitored the depressurization of the hydrogen gas bubble at Three Mile Island through measurements of the primary system of the plant. He also served on a special U.S. Department of Energy Task Force that studied the causes of the Chernobyl Nuclear Accident and made recommendations for corrective actions. For two years prior to his retirement he served as System Engineer for the Spallation Neutron Source Research Facility, an international neutron research complex completed at ORNL in 2008.

Ray has been an active member of Presbyterian churches since high school, having served for over 45 years in the choirs at Cedar Springs Presbyterian Church and later at West Hills Presbyterian Church. He is survived by his beloved wife of fifty-five years Judith, three daughters, seven grandchildren, and his 4 siblings.

*Excerpted from Knoxville News Sentinel from Oct. 18 to Oct. 19, 2017*



#### **Icarus**

*In 1998, the AFIT Foundation initiated, commissioned, and funded, through contributions, the construction of a memorial to graduates of the Air Force Institute of Technology from the Air Force and Army Air Corps who lost their lives while in service to our country. Upon completion, the monument was offered as a gift to the Department of the Air Force and, under the provisions of Title 10, United States Code, Section 2601, accepted.*

*As the story goes, father and son were imprisoned together in the Labyrinth on the Isle of Crete, they escaped on wings fashioned by Daedalus from feathers and wax. But Icarus flew too close to the sun, the wax melted, and he fell to his death in the Aegean Sea as his father flew to freedom filled with sorrow for his loss. Though Icarus fell, he gained his freedom by daring to fly. The Icarus Memorial remembers the graduates of the Air Force Institute of Technology who gave their lives in service to our country.*



# FACULTY HIGHLIGHTS

## AFIT Faculty Member Earns Bronze Star Medal

*Originally Posted Wednesday, November 15, 2017*

Colonel Matthew Douglas is the Dean of Students for AFIT's Graduate School of Engineering and Management's 650+ in-residence students. Douglas is a graduate of AFIT, earning a master's degree in logistics management in 2003.

Colonel Douglas distinguished himself by meritorious achievement as Director of Maintenance, Train, Advise, Assist Command Air, 438th Air Expeditionary Wing, while engaged in military operations involving conflict with an opposing foreign force at Forward Operating Base Oqab, Afghanistan from December 2015 to November 2016.

During this period, in support of Operation FREEDOM'S SENTINEL, and while exposed to significant danger from rocket attacks, insider threats and direct engagements, Colonel Douglas was the senior aircraft maintenance lead supporting a fleet of 111 United States and Russian built fixed and rotary wing aircraft, providing direct oversight of 10 maintenance and logistics support contracts valued at \$782 million dollars.

In this capacity, he conducted 91 outside the wire engagements with Afghan senior leadership, laying the foundation to improve the Afghan Air Force's aircraft fleet health and integrate new aircraft and associated combat capabilities. He led the Fighting Season 2016 maintenance plan which included establishing partnered operations during Ramadan which alleviated mission degradation and enabled 950 Mi-17 combat missions.

Additionally, Colonel Douglas oversaw the A-29 light attack aircraft bed down and maintenance plan, successfully receiving the first eight aircraft in country which ensured initial operational capability of Afghanistan's newest attack platform and its historic first combat employment less than three months after arrival. He conducted site visits to Kandahar and Mazar-e-Sharif Airfields to exploit the combat capabilities of the A-29. He secured vital munitions storage areas which directly enabled 91 air strikes on enemy positions.

Colonel Douglas commanded two expeditionary advisory missions to Shindand Air Base, consisting

of more than 90 personnel.

During these missions his teams conducted crucial advising and aircraft assessment,

as well as the extraction of an Mi-17 aircraft for out of country overhaul. His subsequent recovery plan for Shindand's struggling fleet ultimately increased aircraft availability 25 percent. His individual efforts enabled the organization to capture the 2016 Secretary of Defense Maintenance Award for maintenance training, advice, and assistance of Foreign Security Forces.

The Bronze Star Medal is awarded to members of the United States Armed Forces for either heroic achievement, heroic service, meritorious achievement, or meritorious service in a combat zone. The Bronze Star is the ground equivalent of the Air Medal. Wikipedia states, "Colonel Russell P. "Red" Reeder conceived the idea of the Bronze Star Medal in 1943; he believed it would aid morale if captains of companies or of batteries could award a medal to deserving people serving under them."

Colonel Douglas received his commission in 1996 as a graduate of the Reserve Officer Training Corps program at Angelo State University. He is a career aircraft maintenance officer with operational assignments in flightline and backshop maintenance, air mobility operations, and executive administration. He has served in various capacities, to include squadron command. In 2009, he earned a doctorate in marketing from the University of North Texas.

Colonel Douglas is a member of the Council of Supply Chain Management Professionals, the Logistics Officer Association and the Production and Operations Management Society.



Col Paul Cotelleso, Air University DET 1 Commander and AFIT Director of Staff, presented the Bronze Star Medal to Lieutenant Colonel Matthew Douglas on 24 August 2017.

## Four AFIT Researchers Win Air Force STEM Awards

*Originally Posted Thursday, November 02, 2017*

The Air Force STEM Awards recognize scientists and engineers who make noteworthy contributions to technology and engineering, solving technical problems in development, sustainment, testing, training or advancement of Air Force systems.

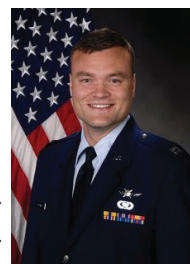


Mr. Eric N. Taylor  
Air Force Outstanding Scientist/Engineer Awards, Engineering Technician Category Physical Science Technician, Department of Engineering Physics, Graduate School of Engineering and Management, AFIT

Captain Aaron J. Canciani  
John L. McLucas Basic Research Award Winner; PhD Electrical Engineering, 2016 & M.S. Electrical Engineering 2012 Assistant Professor of Electrical Engineering, Department of Electrical and Computer Engineering, Graduate School of Engineering and Management, AFIT



Major Jason M. Bindewald  
Air Force Research and Development Award Winner; PhD Computer Science, 2015 & M.S. Cyber Operations, 2012 (Distinguished Graduate) Assistant Professor of Computer Science, Department of Electrical and Computer Engineering, Graduate School of Engineering and Management, AFIT



Capt Bryan R. Bentz  
AFIT Systems Engineering Award Winner; M.S. Systems Engineering, 2017 Executive Officer, Air Force Operational Test and Evaluation Center, Detachment 1 F-35 Joint Operational Test Team, Edwards AFB, CA

## Six Faculty Received Excellence Award

*Originally Posted Monday, November 06, 2017*

Congratulations to the following Graduate School of Engineering and Management faculty members for receiving the 2017 Faculty Excellence Award presented by The Southwestern Ohio Council for Higher Education (SOCHE). The award winners are:

- Lt Col Anthony L. Franz, Assistant Professor of Physics, Department of Engineering Physics
- Dr. Carl R. Hartsfield, Assistant Professor of Aerospace Engineering, Department of Aeronautics and Astronautics
- Dr. Douglas D. Hodson, Associate Professor of Computer Engineering, Department of Electrical and Computer Engineering
- Dr. Brian J. Lunday, Associate Professor, Department of Operational Sciences
- Dr. Michael E. Miller, Associate Professor of Systems Integration, Department of Systems Engineering & Management

- Maj Jonah A. Reeger, Assistant Professor of Mathematics, Department of Mathematics and Statistics



Southwestern Ohio Council for Higher Education

# RESEARCH & DATA

## Selected Large Awards for Fiscal Year 2017

“Strategic Development Planning & Experimentation Support: Roadmap for Multi-Domain Modeling, Simulation, Analysis and Experimentation” \$1M SDPE Principal Investigator: Lt Col Matthew Robbins

“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)” \$800K Office of the Secretary of Defense; Principal Investigator: Dr. Jeffery Weir

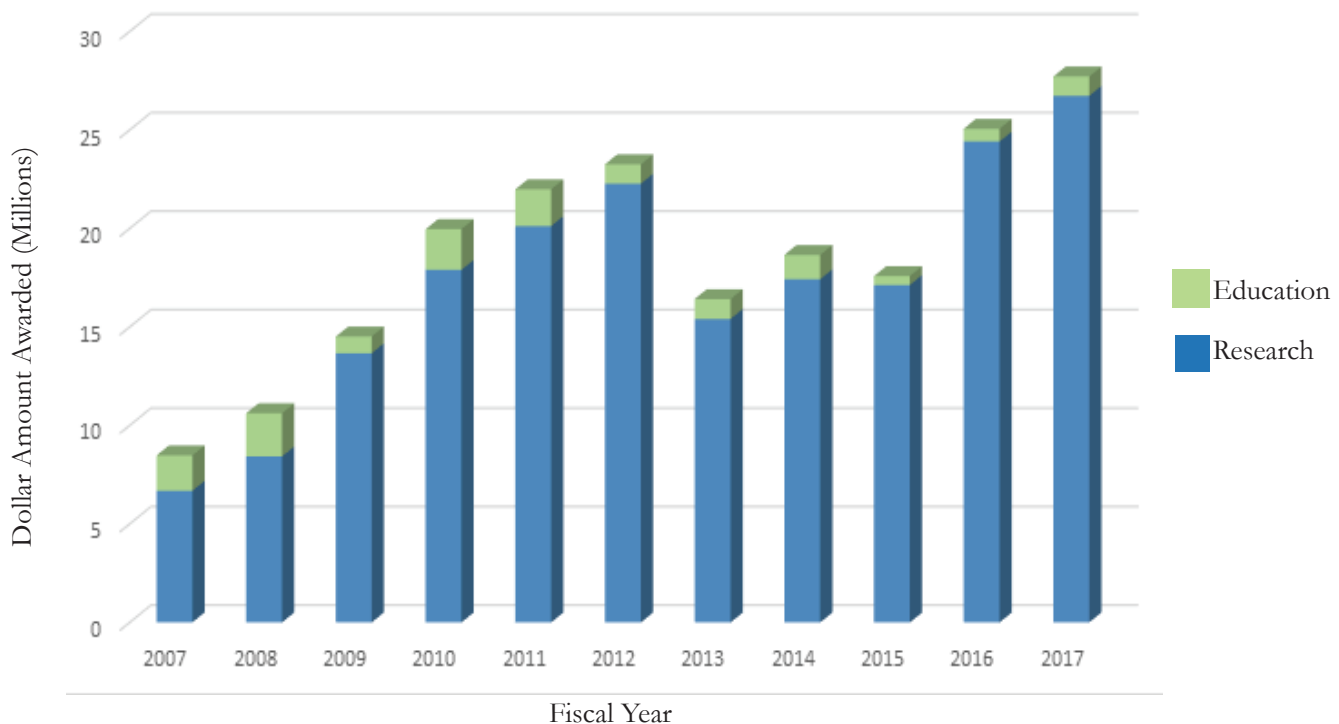
“Development of Cyber Resiliency Processes and Mitigation Solutions for Legacy Platforms” \$700K Air Force Life Cycle Management Center; Principal Investigator: Dr. Jeffery Weir

“AFIT Research in Support of ONR’s US-India OSD-DRDO Collaborations” \$680K: ONR Principal Investigator: Dr. Steve Fiorino

“Logistics Data Environment” \$550K AF/A4; Principal Investigator: Dr. Brad Boehmke

“Department of Homeland Security, Science and Technology Directorate” \$515K, Department of Homeland Security; Principal Investigator: Dr. Darryl Ahner

## New Award History Fiscal Year 2007 - Fiscal Year 2017



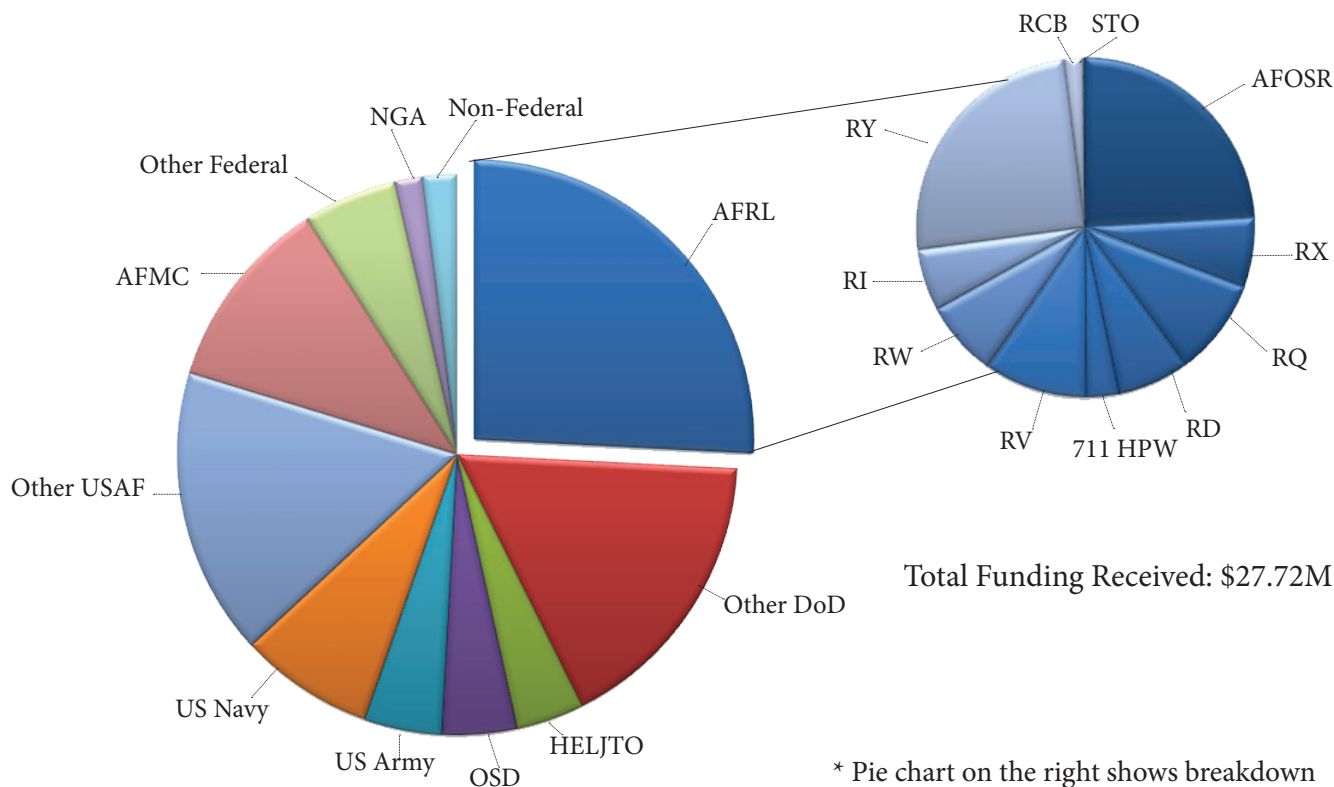
## New Fiscal Year 2017 Awards to Academic Departments and Research Centers

|                                     | <i>Newly Awarded<br/>Research Projects</i> |               | <i>Newly Awarded<br/>Education Projects</i> |            | <i>Total FY17<br/>Newly Awarded<br/>Projects</i> |               | <i>Total FY17<br/>Research<br/>Expenditures</i> |
|-------------------------------------|--------------------------------------------|---------------|---------------------------------------------|------------|--------------------------------------------------|---------------|-------------------------------------------------|
| DEPARTMENTS                         | #                                          | \$k           | #                                           | \$k        | #                                                | \$k           | \$k                                             |
| Mathematics & Statistics (ENC)      | 5                                          | 288           | -                                           | -          | 5                                                | 288           | 539                                             |
| Electrical & Computer Eng (ENG)     | 57                                         | 5,950         | 2                                           | 228        | 59                                               | 6,178         | 7,871                                           |
| Engineering Physics (ENP)           | 54                                         | 5,719         | 1                                           | 9          | 55                                               | 5,728         | 7,066                                           |
| Research & Sponsored Programs (ENR) | 1                                          | 280           | -                                           | -          | 1                                                | 280           | -                                               |
| Operational Sciences (ENS)          | 35                                         | 9,976         | 4                                           | 286        | 39                                               | 10,262        | 11,534                                          |
| Systems Eng & Management (ENV)      | 17                                         | 1,249         | 1                                           | 400        | 18                                               | 1,649         | 1,863                                           |
| Aeronautics & Astronautics (ENY)    | 48                                         | 3,275         | 2                                           | 59         | 50                                               | 3,334         | 6,320                                           |
| <b>TOTAL</b>                        | <b>217</b>                                 | <b>26,737</b> | <b>10</b>                                   | <b>982</b> | <b>227</b>                                       | <b>27,719</b> | <b>35,193</b>                                   |

| CENTERS                                          | #          | \$k           | #        | \$k        | #          | \$k           | \$k           |
|--------------------------------------------------|------------|---------------|----------|------------|------------|---------------|---------------|
| Autonomy and Navigation Technology (ANT)         | 30         | 3,792         | -        | -          | 30         | 3,792         | 5,101         |
| Center for Cyberspace Research (CCR)             | 10         | 668           | 2        | 228        | 12         | 896           | 1,161         |
| Center for Directed Energy                       | 19         | 3,025         | 1        | 9          | 20         | 3,034         | 3,186         |
| Center for Operational Analysis (COA)*           | 24         | 7,516         | 2        | 180        | 26         | 7,696         | 9,640         |
| Center for Space Research and Assurance (CSRA)   | 26         | 2,484         | -        | -          | 26         | 2,484         | 3,549         |
| Center for Tech Intel Studies & Research (CTISR) | 15         | 1,552         | -        | -          | 15         | 1,552         | 1,836         |
| <b>TOTAL</b>                                     | <b>124</b> | <b>19,037</b> | <b>5</b> | <b>417</b> | <b>129</b> | <b>19,454</b> | <b>24,473</b> |

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 2017 Projects



# ENROLLMENT INFORMATION

## 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. The Engineering Accreditation Commission (EAC) and the Applied Science Accreditation Commission (ASAC) of ABET accredits our eligible engineering and applied science programs. Students usually finish their master's programs within two years and the doctoral programs within three years. 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. Our campus consists of eight buildings, 23 class laboratories, 67 research/laboratory areas, and the D'Azzo Research Library.

For more information visit the AFIT Admission's page: [www.afit.edu/admissions](http://www.afit.edu/admissions).

## 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.

For additional information regarding AFIT internship opportunities visit [www.socheintern.org](http://www.socheintern.org).

## 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 contact the Office of Research and Sponsored Programs: [research@afit.edu](mailto:research@afit.edu).

## AFIT Research Centers

|                                                                  |                                                              |                    |
|------------------------------------------------------------------|--------------------------------------------------------------|--------------------|
| Autonomy and Navigation Technology Center                        | <a href="http://www.afit.edu/ANT/">www.afit.edu/ANT/</a>     | Dr. John Raquet    |
| Center for Cyberspace Research                                   | <a href="http://www.afit.edu/CCR/">www.afit.edu/CCR/</a>     | Lt Col Mark Reith  |
| Center for Directed Energy                                       | <a href="http://www.afit.edu/CDE/">www.afit.edu/CDE/</a>     | Dr. Steven Fiorino |
| Center for Operational Analysis                                  | <a href="http://www.afit.edu/COA/">www.afit.edu/COA/</a>     | Dr. Paul Hartman   |
| Center for Space Research and Assurance                          | <a href="http://www.afit.edu/CSRA/">www.afit.edu/CSRA/</a>   | Col Dane Fuller    |
| Center for Technical Intelligence Studies & Research             | <a href="http://www.afit.edu/CTISR/">www.afit.edu/CTISR/</a> | Dr. Kevin Gross    |
| OSD Scientific Test and Analysis Techniques Center of Excellence | <a href="http://www.afit.edu/STAT/">www.afit.edu/STAT/</a>   | Dr. Darryl Ahner   |

## LOOKING AHEAD

### AFIT Prepares for Centennial Celebration

*Ms. Kathleen Scott*

*Kathleen.Scott@afit.edu*

*937-255-3636 x4393*

On 10 November 1919, Colonel Thurman Bane received authorization to begin instruction at the Air School of Application. The following year, the first class of nine students graduated from the newly named Air Services Engineering School. Now, 98 years later, the Air Force Institute of Technology has awarded over 20,000 degrees and more than 400,000 people have gone through our continuing education courses!

As we move closer to our centennial, many events are being planned to remember the people and scientific accomplishments of the past and celebrate the future accomplishments we are working on today. If you would like more information about the plans, or to suggest Centennial Story Highlights, please contact the Alumni Affairs and Institutional Advancement Manager, Ms. Kathleen Scott, at [kathleen.scott@afit.edu](mailto:kathleen.scott@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](http://www.afit.edu/directory_search.cfm).

### Stay connected to AFIT



**Do you have an AFIT memory, story or history that you would like to see highlighted in AFIT's Centennial Annual Report?**

**Contact Ms. Kathleen Scott  
([Kathleen.Scott@afit.edu](mailto:Kathleen.Scott@afit.edu)) or  
Ms. Shannon Tighe  
([Shannon.Tighe@afit.edu](mailto:Shannon.Tighe@afit.edu))  
with your submissions and ideas!**

The AFIT of ***today*** is the  
Air Force of ***tomorrow!***

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