

two thousand and ten
RESEARCH AT

USAFA



Pictured on the bottom: A cadet works in the clean room to disassemble, test and re-assemble the FalconSat 5. FalconSat 5 will be launched from Kodiak Island, Alaska in fall 2010.

Pictured on the top from left to right: The USAFA shield, the Eagle and Fledgling Statue, a sample of black silicon from a joint USAFA/MITRE laser project, and a cadet with rat during the annual learning assessment, Rat Olympics.



USAFA Vision:

To be the Air Force's premier institution for developing leaders of character.

USAFA Mission:

To educate, train, and inspire men and women to become officers of character motivated to lead the United States Air Force in service to our nation.

USAFA Values:

Integrity First ~ Service Before Self ~ Excellence In All We Do

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RESEARCH AT USAFA 2010

"The Air Force Academy is built upon a proud foundation and so it should be. For the Academy is a bridge to the future, gleaming with promise of peace in a stable, sane world....Our airpower has kept the peace...it is keeping the peace, God willing, it will keep on doing so. This Academy, we are founding today, will carry forward that great effort." -Air Force Secretary Harold E. Talbott, July 11, 1955

Over the past 55 years, the US. Air Force Academy has carried forth the calling of its founding and the great pioneers of air, space, and cyberspace have laid the path for the cadets of today to follow. To **educate**, to **train**, and to **inspire** are words that have rung true for every cadet and every faculty member who has passed through the USAF Academy gates. To lead, to fight, and to win in an ever-evolving mission that encompasses new air, space, and cyberspace threats is our greatest modern challenge. In the following pages, you will learn how our faculty, cadets, and core mission elements are being driven and shaped to not only succeed in our mission today but to set the standards to which the rest of the world endeavors to follow in the future.



Educate

The Dean of the Faculty, Brigadier General Dana H. Born, summed up the critical importance of maintaining the USAF Academy's collective efforts in her 2009-2014 strategic plan: "...In teaching our cadets, we feel both the weight of responsibility and the excitement in preparing cadets to be leaders of character who are called upon to defend our nation." Through our 14 research centers and two Air Force policy institutes, our faculty and dedicated researchers are rising to the call to shape and guide the Air Force leaders of tomorrow and to ingrain within them operational education to fly, fight and win in air, space, and cyberspace.



Train

The motto of our Space Systems Research Center is, "learn space by doing space." That belief in training our cadets to think beyond the questions and answers at the back of the chapter and to identify, research, and solve hands-on, real-world problems is the catalyst of learning-focused education. Not only are cadets engaged in Air Force and Department of Defense-relevant research, but they are offered training and development in organizational, communications, and problem-solving skills that can't be learned just in the classroom.



Inspire

If our cadets are inspired by our USAF Academy leadership and faculty, the same can be said in reverse. The research accomplishments of our cadets are great successes: Cadet First Class Thomas Sukut's key contributions to the Air Force ground-based optical surveillance program for Space Situational Awareness (SSA), Cadet First Class Sean Harte's break-through repair technique for enamel coating technology, and the Academy's 36th Rhodes Scholar recipient Cadet First Class Brittany Morreale's work on the sun's impact on radioactive decay rates. These successes are our successes and will inspire our faculty and generations of future cadets to come.

This is Research at USAFA.

RESEARCH AT USAFA 2010



KINDLING THE FIRE OF FANATICAL PRIDE

Building the Leaders of Tomorrow

Lt Gen Mike Gould,
Superintendent, USAFA

When an institution brings together committed faculty with the intellectual curiosity of young minds and offers them the challenge of solving real-world research needs, a perfect storm is born.

This storm, what I like to call "fanatical pride," brings out the very best that we have to offer as an institution and as a nation. It allows us to shape young minds into officers of character who will embody the values of respect,

leadership, and the willingness to look beyond the easy answer. At the same time, it empowers our graduates to enter the active duty Air Force with a burning pride in their accomplishments and in their alma mater.

In 1944, General "Hap" Arnold asked Dr. Theodore von Karman to produce the report that would become *Science: The Key to Air Supremacy*. As we look back on von Karman's recommendations and Gen Arnold's leadership, their shared vision that shaped our Academy is startling in both its perception of the future and its continued relevance to our ongoing efforts today. In 1945, von

Karman called for the development of research centers throughout the Air Force that would directly address Air Force-wide issues with the most modern scientific equipment and minds available. We have seen this vision thread throughout our 14 research centers and two Air Force policy institutes operating here at the Academy.

Dr. von Karman went on to call for the development of pilotless aircraft and the development of officers to oversee these new aircraft operations. Today, we have played our role in making von Karman's and Gen Arnold's vision of unmanned aerial systems (UAS) and remotely piloted aircraft (RPA) a reality, and we are on the frontlines of developing future Air Force officers to research, develop, operate, and manage the UAS-RPA fleet of tomorrow's Air Force.

Finally, von Karman called for the officers in charge of the Air Force to "always remember that problems never have final or universal solutions, and only a constant inquisitive attitude toward science and a ceaseless and swift adaptation to new developments can maintain the security of this nation through world air supremacy."

Today, the supremacy of our nation is not reliant just upon our dominance in the air but also in space and cyberspace. We are also challenged in today's global missions to win the hearts and minds of those we serve both at home and abroad. We are challenged to be mindful of our broader obligations to

our families, our cadets, our fellow faculty members, and our fellow citizens.

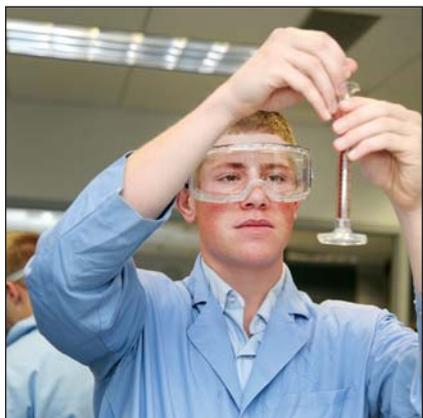
We are challenged to develop officers who will not only lead our nation in science and technology but who will also be leaders of character. And again, we are rising to meet these challenges.

Through our Center for Character and Leadership Development, we will further our mission to shape cadets' character and development as leaders. Our faculty and staff across the board will both contribute and benefit from this integrated effort as will our greater Air Force community and nation.

In the following pages, you will see how the thread carefully laid out by von Karman half a century ago has wound its way throughout the fabric of each of our research centers and institutes, through the fabric of our dedicated faculty and staff, and stitched into the details of our cadets' character and leadership development. I encourage you to look closely at this magnificent cloth that makes up the fabric of each Air Force Academy graduate as they begin their next journey as Air Force officers.

I am sure that you will share my pride in this cooperative effort to light the fires of their minds and to fan the flames of pride in our cadets, faculty and nation.


Lt Gen Mike Gould
Superintendent, USAFA



RESEARCH AT USAFA 2010



RESEARCH IN LEARNING-FOCUSED EDUCATION

High-Impact Learning = Fanatical Pride

Brig Gen Dana H. Born,
Dean of the Faculty, USAFA

When we think of cadet learning at the United States Air Force Academy, we envision a culture where cadets gain the knowledge, skills, and responsibilities necessary to succeed as future officers of character who are prepared to tackle the evolving challenges facing our Air Force and our nation.

Research plays an integral role in our learning-focused education. Through our world-class research laboratories and institutes, cadets and faculty have the opportunity to be a part

of tomorrow's solutions today. By integrating intellectual and warrior skills, cadets develop critical thinking, analytical skills, and the professional ethics required to be successful in ever-changing technical and physical environments. Research builds stamina, discipline, decision-making, teamwork, and strong oral and written communication skills – all of which will serve them well as their careers in the Air Force advance and begin to shape future Air Force policies and actions. Guided by military and civilian faculty members, cadets learn to “think outside of the box” and to respond to scenarios that often do not offer clear answers that require independent thinkers.

Today, the USAFA research program has an annual value of \$52.4 million, and it continues to grow. With nearly 90 Cooperative Research and Development Agreements, our cadets and faculty have the opportunity to directly contribute to academic and commercial, Air Force, Department of Defense, and Department of Energy projects. Also essential to the success of this program are USAFA's partnerships with supporting agencies including the Air Force Office of Scientific Research, our longest-standing sponsor, and the Oklahoma City Air Logistics Center, our largest financial supporter. I am grateful for our sponsors' continued enthusiasm and support for what has become one of the **largest undergraduate research programs in the nation.**

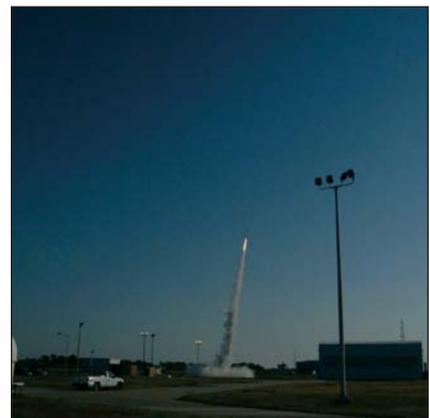
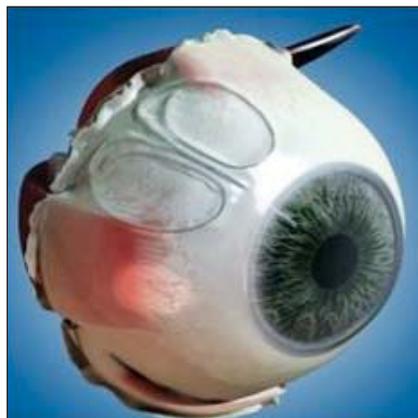
The Cadet Summer Research Program (CSRP) has also become an essential part of USAFA's learning-focused goals. Approximately 180 rising first class cadets participate in CSRP, where the average research project is three to five weeks long. The success of CSRP has – simply put – been phenomenal. Recent projects include test and analysis of the NASA Orion Crew Module parachute recovery system for the Johnson Space Center; design of a low-cost, persistent unmanned aerial vehicle for potential Special Operations use; and assessment of China's counter-space program that was ultimately forwarded to the Secretary of State. These accomplishments highlight the impact of our faculty mentors and make me proud of our cadets and our Academy.

This report is a brief introduction to the Academy's 14 research centers and two institutes. These centers and institutes demonstrate our commitment to our belief that "cadet success is our success." The research opportunities available at USAFA are limitless and multi-disciplinary, and include "eye-safer" lasers, renewable energy, advanced computational fluid dynamics, cyber warfare response, new battery technologies, national and space security, and the development of new technology innovations which not only speak to today's Air Force needs, but open the doors and windows into tomorrow's scientific and social advances.

The future will continue to offer new leading-edge research and education opportunities. I am confident we will rise to the challenge of providing our cadets the intellectual foundation to lead our Air Force and our nation in the future. I invite you to explore this report and get a taste of these exciting avenues of discovery.



Dana H. Born, Brigadier General, USAF
Dean of the Faculty





THE CENTER FOR CHARACTER & LEADERSHIP DEVELOPMENT

Fanning the Flames of Fanatical Pride

The Center for Character & Leadership Development (CCLD) fosters the growth of character and leadership in the cadets and staff at the Academy. Its mission is to advance the understanding, practice, and integration of character and leadership development in preparation for service to the nation in the profession of arms. Its staff are committed to creating and shaping an Academy that celebrates character and promotes the integration of these values throughout the broader Air Force. The CCLD provides world-class education and experiences for cadets and staff, enlightening and equipping future officers to advance the lifelong habit of honorable living.

Comprised of four divisions - Capstone Events, Honor, Education, and Scholarship – the CCLD is working to ingrain character and leadership development at every stage and stop along a cadet’s path to officer.

Our recent Commandant of Cadets, Brigadier General Samuel D. Cox, described the mission of the Academy and CCLD, “USAFA’s primary mission is to produce leaders of *character*, therefore it is imperative that we aggressively and responsibly focus our efforts to meet this end. We have a proud heritage of developing outstanding leaders who have strong integrity and commitment to our Air Force core values, but excellence requires a relentless pursuit to continuously improve our programs as well as methods of measurement. The Center for Character and Leadership Development exists to forward that goal, to be the premier center for promoting the development of character and leadership, both here at USAFA and throughout the Air Force.”

The Capstone Events division hosts the National Character & Leadership Symposium (NCLS) and the Falcon Heritage Forum (FHF).

NCLS brings together distinguished scholars, military and corporate leaders, athletes, and others to share knowledge and insight which enhance the understanding and challenges of sound moral character in leadership positions. FHF links cadets with the wealth of knowledge and experience embodied in our distinguished veterans. This interaction gives practical and honest answers to operational Air Force issues. The Honor division works to develop moral habits to build a foundation of integrity and leadership. The Education division puts on five character seminars and core values training for the cadets to further develop values, courage, respect for others, servant leadership and ethical reasoning and action.

The Scholarship division was recently created to generate diversity of thought and innovation that takes theory into practice. This division proactively and accurately assesses, analyzes, and refines the effectiveness of developmental programs and facilitates practical evaluation of character and leadership education. Assessment ensures CCLD's programs are reaching its goals and understanding of the impact of events on cadet development and learning. The Scholarship division also released its first publication, the *Journal of Character and Leader Scholarship (JCLS)*, in December 2009. This publication publishes leading edge research and facilitates a connection of diverging worldviews. The JCLS is a transformative forum for conversations that foster new ways of thinking about and relating to character and leadership.

Staff members and cadets from the CCLD advance their knowledge and development by attending leadership conferences around the country at universities and other military institutions such as the International



Society for Military Ethics Conference, Military Academies Honor Conference, and the University of San Diego Character Development Leadership Conference.

USAFA also hosts many conferences, trainings, events and symposiums on character. Internally, it hosts various professional development days during which notable guests speak with the staff about ways to advance our training techniques and methods. It also hosts the Platinum Lecture Series which is open to both cadets and USAFA permanent party. This series brings in such speakers as Dr. Kevin Ryan, the founder and director emeritus of the Center for the Advancement of Ethics and Character at Boston University, and Dr. Dave Logan, author of *Tribal Leadership* and *The Three Laws of Performance*.

Of the numerous changes that have come about this last year, one of the most significant is the establishment of a Permanent Professor chair and filling it with Colonel Joseph Sanders who is also the Center Director. Additionally, the CCLD's first senior scholar, Dr. Arthur Schwartz will provide the necessary academic rigor to the center's future.

The CCLD has many future goals for its programs, events, and scholarship expansion. We strive for innovative instruction and research into the study and practice of character and leadership. We aim to continuously learn and adjust to the demands of change and challenge established worldviews about character and leadership. There have been many changes in the 21st century militarily, culturally, technically, politically and operationally. These changes generate challenges which require new approaches to developing character and leadership. The aim of the Journal is to become a world resource for scholarly and practical discourse on the constructs, concepts, and contexts of character and leadership development and increase international engagement on the subject. The CCLD will endeavor to be USAFA's catalyst for achieving its highest purpose, to develop officers of character, and to establish the Academy as an epicenter of character and leadership development.





HUMAN PERFORMANCE LAB

Enhancing Airman Readiness

The body of the airman is as important to mission success as technology and arms. The USAFA Academy's Human Performance Lab (HPL) is a key element to identifying how the Air Force can keep our airmen physically safe as they complete their missions in a wide variety of terrains.

Under the direction of the USAFA Athletic Department and retired Brigadier General Hans Mueh, the HPL applies sports science principles to improve Academy athletic teams and individual cadet performance. Coaches, cadet athletes and cadets receive specific physiological information by way of testing, research, training and education.

The lab also provides subject matter expertise on the Air Force fitness program and human performance, offering scientific data through

research and exercise science principles. As a result, the HPL offers a venue for cadet researchers and qualified exercise physiology interns to complete independent study research in the fields of exercise physiology, biology, biochemistry and biomechanics.

The HPL tests and trains more than 1,000 cadets and approximately 100 faculty and staff members annually.

Some of the projects undertaken by the HPL are joint efforts with the Air Force Research Lab (AFRL) and with the Academy's Life Sciences Research Center. Most HPL projects offer cadet research components as well as direct Air Force or Department of Defense field applications.

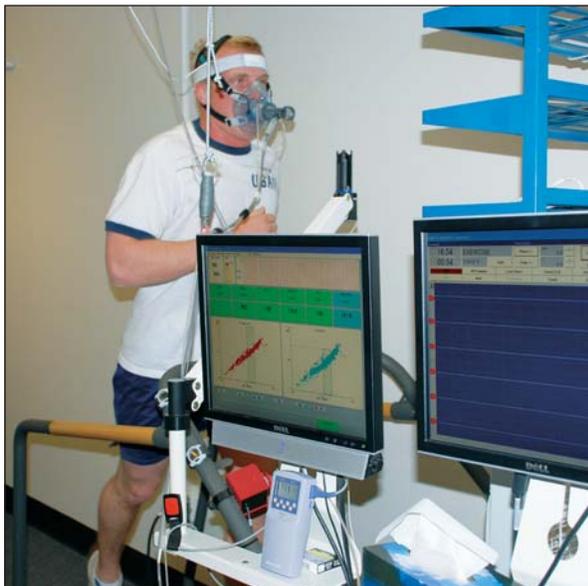
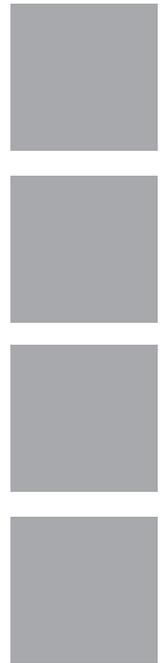
One of the main research projects for the 2009/2010 AY was the on-going data analysis of the USAFA Moderate Altitude

Acclimatization and Iron Supplementation study, which was an Air Force Surgeon General-funded, year-long, double-blind, placebo-controlled study which involved nearly 100 cadet subjects, six cadet researchers and twelve 499 Independent Study semester hours. It was also supported by AFRL. The study examined the chronic adaptations (hematological and physiological) to moderate altitude among freshman—either former sea level or moderate altitude residents. The final stages of data analysis, which has been occurring in fall 2009 and spring 2010, is the assessment of the changes in running economy with longitudinal altitude adaptation, and an examination of various individual genetic factors and their relationship with the large individual variability observed with the acclimatization process. This cadet research has been recognized with first and second place awards at regional conferences as well as presented at multiple international scientific conferences. The data results showing lengthy altitude acclimatization yet rapid de-acclimatization of subjects' total hemoglobin mass puts airmen at a physiological disadvantage when performing or returning to higher altitudes, and will also be presented at the Air Force Medical Symposium in Washington DC in Aug 2010.

"The academy is often called a 'leadership laboratory.' The 499 Independent study is a direct extension, providing cadets incredible, hands-on opportunities to become involved in cutting edge research, and learn the challenges and rewards of scientific research," said Assistant Athletic Director and HPL Professor, Lt Col Michael Brothers.

Researchers for the HPL have also acted as a co-primary investigator for a Joint Combat and Casualty Research Team (JC²RT) study being conducted in-theater in Afghanistan. This study examines the prevalence of iron deficient, iron depletion, and iron deficiency anemia in-theatre among military personnel, both male and female. This study was designed and supported as a result of the findings of our previous altitude acclimatization studies here at USAFA, where over 1/3 of the former sea-level freshmen (both male and female) cadet subjects became iron depleted or anemic during their freshman year at USAFA, resulting in detrimental exercise performance, and possible decrements, cognitive performance.

This seminal work in uncovering a better understanding of how individuals truly adapt to changing altitude conditions, especially under challenging physical conditions in a military training environment, is making significant contributions to enhancing airmen readiness today.





SPACE SYSTEMS RESEARCH CENTER

Learning From Mistakes Critical to Forging Success

The motto of the Space Systems Research Center (SSRC), "Learning Space by Doing Space," also includes cadets sometimes having to learn from their mistakes. This premise was one of the most important lessons of the 2009/2010 AY for SSRC cadets.

FalconLaunch is one of the center's marquee programs allowing cadets to design, build, analyze, and launch sounding rockets. In November of 2009, cadets conducted a test fire of a re-designed rocket booster. The result was an impressive explosion, leaving the cadets to reconstruct and solve where their senior capstone project had gone wrong. The team dug in and, utilizing their experience, and the help of industry experts, identified where they had gone wrong in their design. They then corrected the mistake and successfully test fired a second rocket in early 2010. At Fort Carson's Piñon Canyon Maneuvering Site, less than six months after their failed test fire, cadets successfully launched the first-ever, undergraduate-built launch vehicle to fly a Department of Defense Space Experiment Review Board (SERB)

approved payload. The payload, known as ExFIT, was sponsored by the Air Force Institute of Technology, and the experiment successfully demonstrated the use of winglets on supersonic, reusable launch vehicles for future Air Force space applications.

"Probably the most important thing we do in the SSRC programs is to allow our cadets to fail. We've blown up rocket engines, tested satellites to failure, found problems, fixed them, and briefed the whole experience to senior DoD officials," said Astronautics Department Head Col Marty France. "Most undergraduate engineers don't get that kind of experience until they've spent years in the industry. Sometimes, I really don't think this all sinks in with our cadets, but I know they'll appreciate the experience when they're out in the real world making tough decisions."

FalconLaunch is only a part of trio of successful research programs coordinated by the SSRC. FalconSat and FalconOPS are the two other capstone programs within the center. All three programs are bi-annually reviewed

by approximately 80 reviewers from the aerospace community including the Air Force Under Secretary for Space, Air Force Space Command Chief Scientist, the Aerospace Corporation, Lockheed, United Launch Alliance, the Air Force Research Laboratory (AFRL), and the National Laboratories.

FalconSat has been the premier capstone program within the SSRC and the Department of Astronautics for over a decade and is the sole undergraduate-only program of its kind where cadets design, analyze, build, and launch a small satellite on DoD launch vehicles. Completed over the course of three years, FalconSat offers a multi-disciplinary experience for up to 40 cadets each academic year with broad exposure to Astronautical Engineering, Physics, Electrical Engineering, Systems Engineering for Astronautics as well as Management, and Space Operations. FalconSat-5 is a multi-million program sponsored by the AFRL and is the most technically advanced satellite to date built by the FalconSat program. With a fall 2010 launch scheduled, FalconSat-5 will perform on-orbit thruster and space environment characterization experiments.

FalconOPS is the third program component of SSRC. The world-class ground operating system this year welcomed two 18 foot radomes to serve as the downlink node for the soon-to-be launched FalconSat-5. The operations center is currently conducting its third year of on-orbit operations for FalconSat-3, collecting valuable data from its on-board Micro Pulsed Plasma Thruster Control System (MPACS) for AFRL. Cadet ground operators executed a 4 km close fly-by with Cibola, a Department of Energy experimental satellite. In 2010 images of FS-3 were collected to analyze attitude and motion and the exercise helped Cibola's team improve pointing and imaging capabilities.

"Offering an interdisciplinary capstone experience to our cadets that closely mimics a real-world development and acquisition program with real customers is the best way I know for our cadets to exercise what they've learned in the classroom and get a glimpse into the often ambiguous and challenging world of space research and development," said France.



Summer cadet research, graduate opportunities, and support of regional Science, Technology, Engineering and Mathematics (STEM) education efforts are also key contributors to SSRC's on-going successes. Seven astronautics cadets participated in the 2009 Summer Cadet Research Program, conducting a myriad of research with a variety of partners including NASA, AFRL, United Launch Alliance, and the French Air Force Academy (Ecole de l'Aire). A dozen 2010 graduates have been accepted into graduate programs including at the Massachusetts Institute of Technology, Rice University, and the Air Force Institute of Technology.

In addition to building the future science and technology leaders of the Air Force, SSRC and the Astronautics Department have committed to helping build the nation's future scientists and technologists through a variety of STEM efforts. Faculty and cadets hosted hundreds of regional students and educators throughout the 2009/2010 AY. These efforts included hands-on teacher training, visits to local classrooms for demonstrations, hosting 600 high school students from across the country during the annual Summer Seminar program, more than 300 cadets and ROTC cadets from more than 25 universities for the 10-day "Space for All" program, hosting numerous tours of the SSRC and the ground operations center, and partnering with local high schools for various projects including the launching of a weather balloon with a camera payload.





SPACE PHYSICS AND THE ATMOSPHERIC RESEARCH CENTER

"SPARCing" Passion for Space Physics

The mission of the Space Physics and Atmospheric Research Center (SPARC) is to educate the next generation of space leaders by giving cadets real world research problems in space and atmospheric physics. "SPARCing" their interest in space spectrometry, space and atmospheric sensors, and future space payload development is the first step to developing a cadre of space and atmospheric professionals for the Air Force.

led by Dr. Geoff McHarg, SPARC personnel insist that every research project has direct or future cadet involvement. "We will not accept outside funding for a project unless

we can have cadets involved," said McHarg. His insistence on cadet involvement in funded projects has resulted in providing cadets with the real-world project management and research skills they could not otherwise get from traditional classroom instruction.

The SPARC's consistent track record has elevated their status and respect among the national space community. Repeat customers include the Air Force, the Department of Defense (DoD), NASA, the Naval Research Laboratory, and the DoD Space Experiments Review Board (SERB). Additionally, the NASA Shuttle has launched various SPARC payloads into orbit and

there are several SPARC experiments operating on the International Space Station. In 2010, more than a half dozen cadets briefed or presented their research to Air Force leadership and at the SERB.

Examples of SPARC's successes include C1C Jack Fitzgerald, who took third prize at the American Institute of Aeronautics and Astronautics annual student competition and C1C Shane Fink was awarded the Charles Stark Draper Laboratory scholarship to the Massachusetts Institute of Technology for his work on the development of the Miniaturized Atmospheric Neutral Gas (MANG) sensor for the NASA Sounding Rocket Experiment for Neutral Upwelling (RENU).

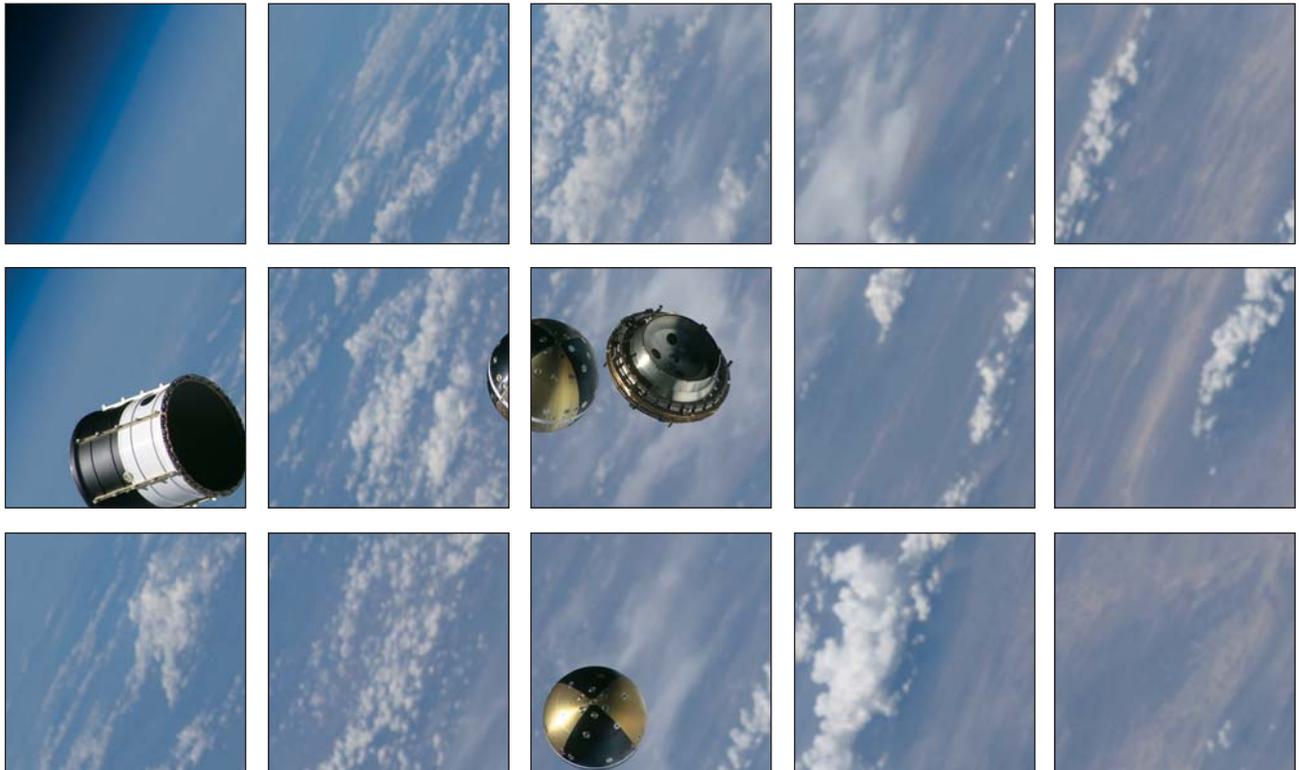
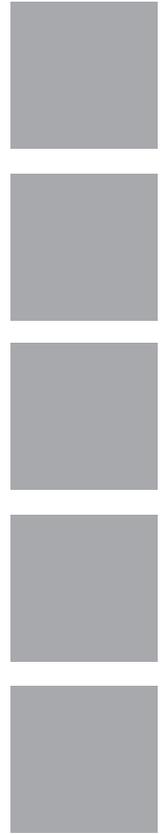
"These are great examples of the "cradle to grave" experience cadets obtain while working with the SPARC," said McHarg.

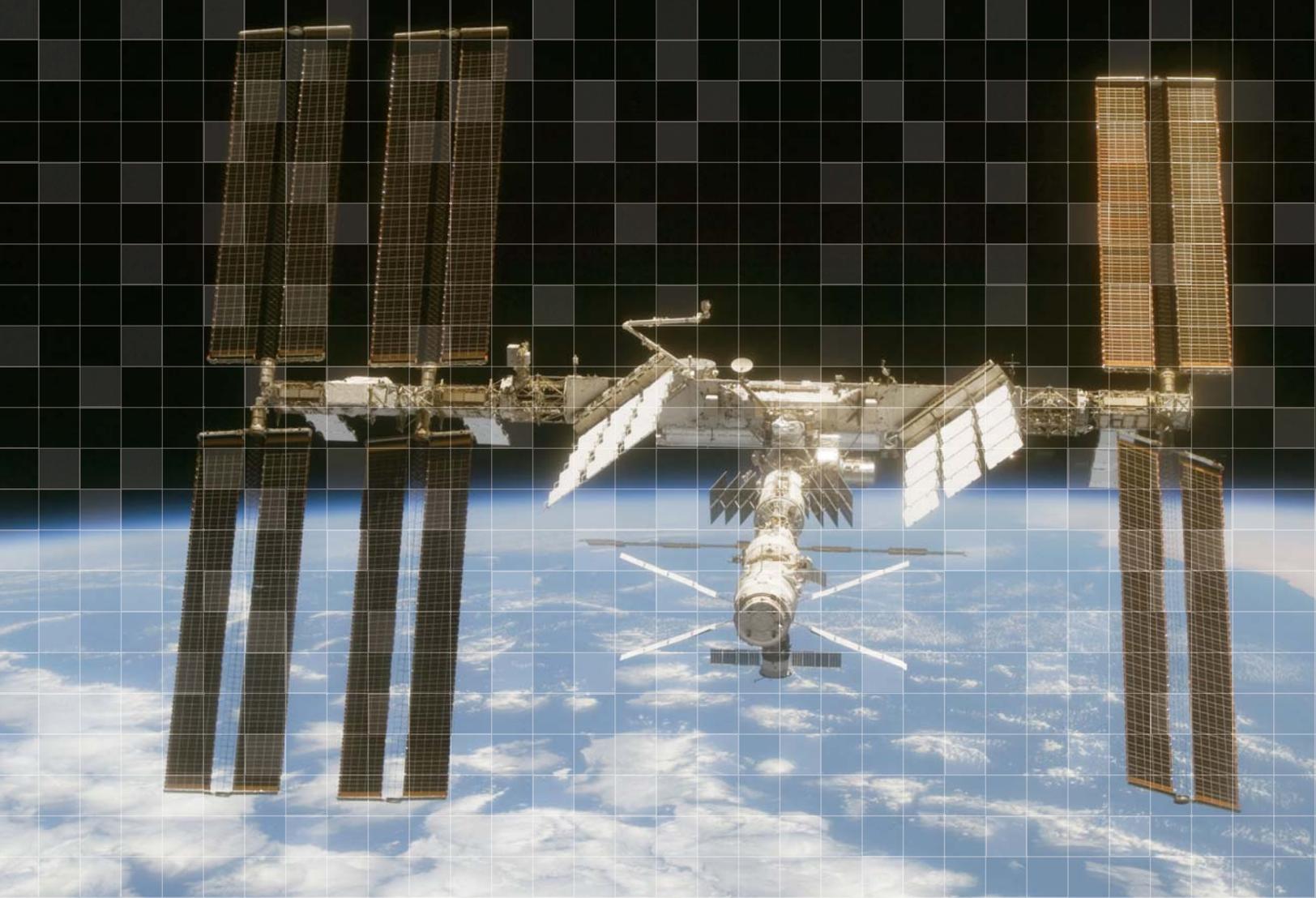
In addition to offering new projects for cadets to develop, SPARC also continues their research on measuring sprite spectra and their principal on-going projects of the Wafer Integrated Spectrometers (WISPERS)

sensor, the Integrated Miniaturized Electrostatic Analyzer (iMESA) payload, and Canary, the WISPERS off-shoot project.

The fact that this work is conducted by undergraduates makes the research component, and ultimately, the mission-impact value of SPARC activities, exceptional.

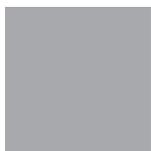
"Research is a unique part of the Academy undergraduate educational experience in that it provides the cadet a chance to take part in a truly "ill defined" problem. No one knows how to solve the problem when you start the research process. This allows the cadet that "ah ha!" moment when they realize that their thoughts, their efforts, and their dedication is what will make the program succeed or fail," said McHarg. "We start out a semester "teaching the cadets" and somewhere in the middle of the semester, we turn into "mentors" making suggestions. By the end of a research project, the cadets are our "peers"- more often than not making suggestions that drive where our project is going. This intellectual growth is the true essence of education."



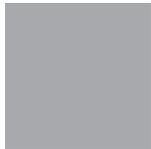
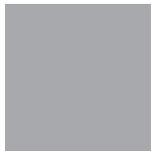


ACADEMY CENTER FOR SPACE SITUATIONAL AWARENESS RESEARCH

Eyes to space helps ground mission



The Academy Center for Space Situational Awareness Research (CSSAR) arrived at USAFA in summer 2009 bringing a new focus to the curriculum on a mission of vital importance to U.S. national security and cadet education. Space is becoming more congested, contested, and competitive and so the mission of the CSSAR is to develop a world-class Space Situational Awareness education and research program for cadets, faculty and the Air Force. Augmenting the existing talent within the Physics Department with a couple of new professors, CSSAR has experts in satellite tracking and characterization, modeling and simulation



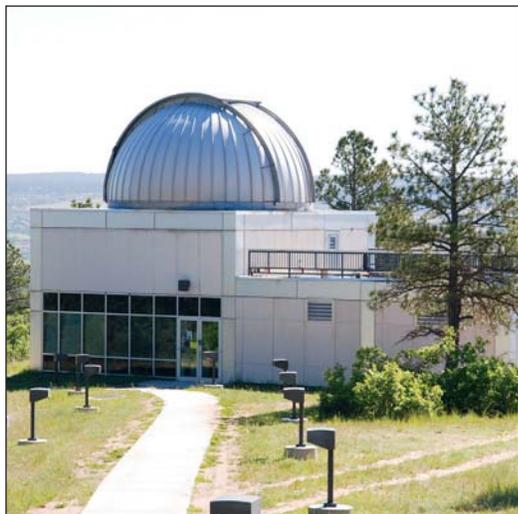
on high-performance computers, telescope and radars.

The CSSAR assisted in the development of a Cadet Summer Research Program (CSRP) project by Cadet First Class (C1C) Daniel Fulcoly at the Maui High Performance Computing Center. Dr. F.K. Chun said "Fulcoly developed a new algorithm for automatically determining the shape of a simple satellite independent of its size, material, and attitude using photometric signatures." Fulcoly was selected as the Basic Sciences Division nominee for the Thomas D. Moore Award recognizing the outstanding CSRP project. Fulcoly's work is

published by the Maui Economic Development Board and was one of several nominees for the Air Force Cadet Research Award.

One facet of CSSAR is course development that will enhance cadet knowledge of Space Situational Awareness. An example of this effort is the establishment of the Physics of Space Situational Awareness course, developed by Dr. Michael Dearborn and offered every spring semester for cadets. According to Chun, the course will “provide the motivation for all research undertaken by the center.” Cadet research during the 2009/2010 academic year (AY) prompted three major projects that were presented at the annual Colorado Springs Undergraduate Research Forum (CSURF). Cadet projects included research in Non-Resolvable Space Object Identification (NRSOI), lucky imaging, characterization of the astronomical seeing conditions at the Academy, and spectral analysis of the International Space Station. Cadets also presented their research at the Advanced Maui Optical and Space Surveillance Technical Conference which is the leading international conference for Space Situational Awareness research.

Lucky imaging is known as the “poor man’s” adaptive optics technique used to capture clear images derived from ground-based telescopes without the need for complex and expensive adaptive optics. Under the direction of Dr. Devin Della-Rose and Dr. Roger



Tippets, cadets recently developed procedures to increase effectiveness of conducting lucky imaging with the Academy’s 24-inch astronomical telescope, demonstrating this technique by imaging the International Space Station. C1C Mason Gordon and C1C Taylor Coffey were able to provide valuable information on the limitations of this technique using a telescope designed to track stars and not satellites.

The research element of undergraduate level education is strongly encouraged by Chun and his team. “The importance of research in undergraduate education cannot be understated and ignored. Students learn by being engaged and research will definitely engage them,” said Chun.

The center is also integral to bringing space and science to the next generation. Science, Technology, Engineering, and Mathematics (STEM) activities at the Observatory public tours draw in over 300 guests annually. “Whenever you can get cadets in front of K-12 students, they are able to show their enthusiasm and excitement and this is a good thing for our country,” said Chun. CSSAR is also partnering with several colleges around Colorado to develop an extensive network of small telescopes for Space Situational Awareness research. This Falcon Telescope Network will provide Colorado communities STEM outreach opportunities by opening up the night sky to them. “There is nothing like looking at celestial objects such as the moon, planets, stars, nebula, and galaxies through a telescope to bring out the excitement and elicit oohs and ahs in children and adults alike.”

Chun has acute awareness of the needs for student research and leads the evolution and adaptation of the curriculum. Professors of the department meet this need to address issues of national security without compromising the basic fundamental knowledge and skills any college graduate requires to be an informed citizen. “The research program and Air Force faculty must be keenly aware of the pressing national security issues facing our nation,” said Chun.





THE EISENHOWER CENTER FOR SPACE AND DEFENSE STUDIES

Space Bolsters National Security

The Eisenhower Center for Space and Defense Studies was established as the research center for the Department of Political Science to give a renewed focus to the Department's fifty year tradition of defense policy studies. The Center's most recent efforts have been organized to provide innovative space policy research, applying a rigorous intellectual foundation from the defense policy studies discipline to new and emerging questions in the space domain. The Center serves to increase the Academy's teaching capabilities and encourage cadets to see the professional challenges that will confront them in their Air Force careers. The Eisenhower Center develops and promotes educational resources to understand the role space systems play in overall U.S. defense and strategic policy, contributing not only to enhancing military capability but also to

achieving overall U.S. foreign and strategic policy goals.

Led by Ambassador Roger Harrison, the Eisenhower Center has greatly increased the resources the Academy devotes to space, including the publication of its *Space Defense Policy* textbook, the continued expansion of graduate study opportunities in space policy for cadets, funding cadet and faculty research projects, and bringing cadets together with senior officials and other experts in workshops on key space policy issues facing the United States. These workshops have included a series of discussions on topics ranging from improving space situational awareness, the dynamics of US-Chinese strategy and security in space, and trans-Atlantic space cooperation.

The Center is named in honor of Dwight D. Eisenhower. Eisenhower was the first American president to establish a national policy shaping US engagement in space for both military and peaceful purposes. His legacy — the creation of both the National Reconnaissance Office and NASA— laid the foundation for the manned space program, the use of space to bolster national security, and the infrastructure which led to revolutions in battle management and global communications. This foundation remains the benchmark against which all successive policies are measured.

The Eisenhower Center has also fostered inter-service education, highlighted by the Summer Space Seminar, a selective two-week program for cadets from Air Force, Annapolis and West Point, along with selected civilian colleges. Cadets have the chance to visit and learn about the key issues and institutions of the industrial, civil and military space sectors.

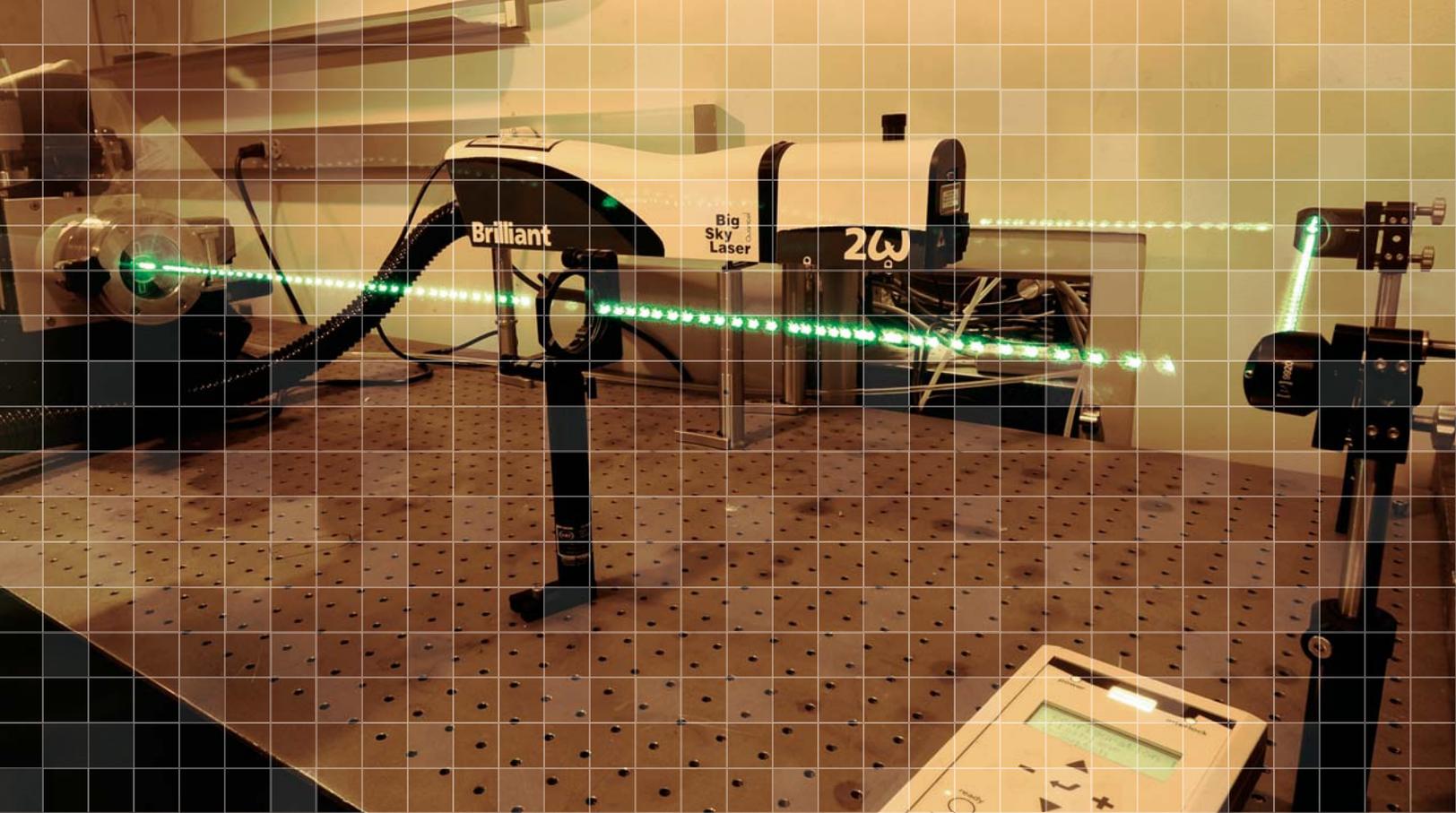
This year marked the first year of teaching by the Brent Scowcroft Professor in National Security Studies. The Scowcroft Professorship is held by Dr. Schuyler Foerster and recognizes the contributions to national security made during the military and civilian career of Lieutenant General Brent Scowcroft, who served as a faculty member of the Department of Political Science when he was a field grade officer.

Like other research centers at the Academy, the Eisenhower Center also makes significant contributions to the needs of the Air Force and Department of Defense at large. A recent example is the Space Deterrence study conducted on behalf of the Office of the Undersecretary of Defense for Policy which provided the first clear intellectual framework for adapting deterrence theory to space systems. The Center's landmark deterrence study has subsequently been used in Washington, DC, for discussions leading to the Quadrennial Defense Review and the new national space policy.

Ambassador Harrison explained that the goal of the Eisenhower Center is to mentor cadets in technical and non-technical majors interested in space policy, encourage research and publication on space policy topics, and to ensure the Air Force has a cadre of future leaders familiar with and inspired by the challenges of operations in space.

"When we think about space, we tend to think about it technically. We need to think about it politically and strategically." He added that the space domain confronts the war fighter with distinct challenges, both operationally and in terms of policy. The Center's task is to prepare them for those challenges, giving them the opportunity for cutting edge research and to nurture them as future leaders of the greatest aero-space force in the world.





LASER AND OPTICS RESEARCH CENTER

Solving Problems at the Speed of Light

The Chinese lunar calendar has the Year of the Dragon. Laser and Optics researchers have the Year of the Laser. 2010 marks the 50th anniversary of the creation of the laser by the late Dr. Theodore Maiman. Laser technology has advanced light years since the Maiman laser was unveiled on May 16, 1960. From its original ruby and gas lasers of the 1960's to today's most advanced photonic crystal fiber lasers and photon sieve holographic optics, the Laser and Optics Research Center (LORC) at the Academy continues to pioneer the edges of laser and optics technologies.

Research at the LORC falls into five broad categories – alkali vapor lasers, atomic physics, fiber lasers, high-performance imaging, and nanotechnology – married with the mission of enhancing cadet

learning through high-impact undergraduate research, the development of faculty through research, and the support of Air Force, DoD, and national technology research and development needs.

Researchers and cadets in the LORC had a very successful 2009/2010 AY. Significant power gains were achieved in the area of transverse pumping of alkali vapor lasers. In the area of atomic physics, researchers were able to observe non-linear pressure dependence of an energy transfer machine for the first time.

LORC Director, Major Ben Ward, demonstrated beam quality improvements through the use of a novel photonic crystal fiber design and pioneered a new method of increasing fiber laser output power through random acoustically micro-structured photonic

crystal fiber. Additionally, Ward partnered with Crystal Lake, Illinois-based Optical Engines, Inc. to invent and demonstrate a new compact and reliable method of pumping photonic crystal fiber lasers.

"Photonic crystal fiber lasers are outstanding candidates for air and space applications due to their high efficiency, light weight and excellent beam quality. They are difficult to study due to the complex physics governing their behavior; however, we relish this challenge," said Ward.

Dr. Geoff Andersen, a researcher in the LORC, continued to demonstrate optics advances in faster and more compact holographic adaptive optics techniques suitable for image correction on highly mobile electro-optic sensor platforms. Andersen has also continued his pioneer efforts in the development of photon sieve telescope optics capable of being deployed from packages with sizes that are a fraction of their optical aperture.

In the area of nanotechnology, LORC researchers have demonstrated a new method of creating the efficient solar cell material "black silicon" and realized the first intrinsic phonon-photon super-lattice meta-material.

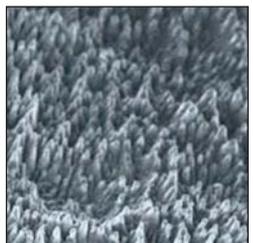
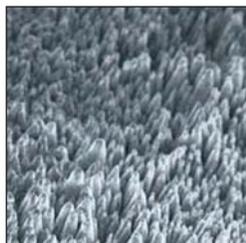
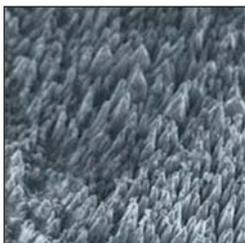
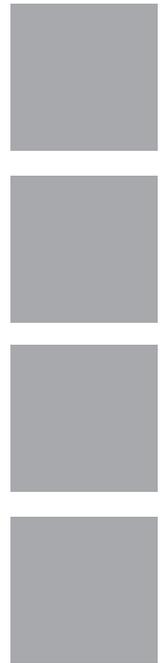
Cadets are involved in multiple capstone and external customer research efforts. Cadets also participate in the annual Cadet Summer Research Program (CSRP) and the center supports the Academy's and DoD's STEM outreach efforts. Recent CSRP successes include a study of optical damage pre-cursors in the National Ignition Facility amplifier chains by C1C Tim Genda, as well as new electro-optical space situational awareness concepts at the National Reconnaissance

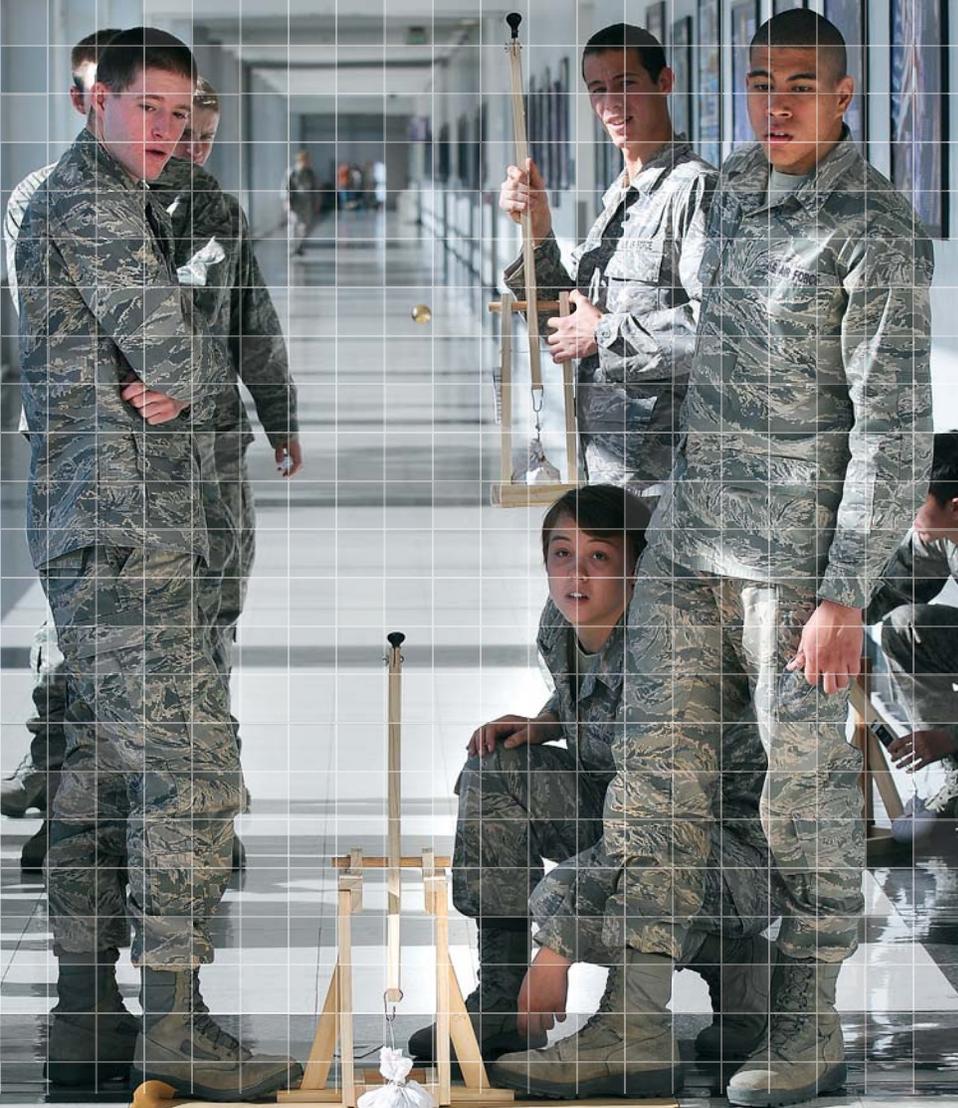
Office by C1C Ben Naumann. Our cadets have also made 3 national presentations and are included as co-authors on 3 publications. Our CRADA partners this year have included General Dynamics, Lockheed Martin and HUA Inc., and we have initiated an inter-service agreement with the Lawrence Livermore National Laboratory to cooperate on the development of next-generation photonic crystal fiber lasers.

The LORC is also a popular destination for students during STEM outreach activities such as Summer Seminar, the NASA Summer of Innovation and for local students.

"Performing research allows cadets to participate in the thrill of the chase for new scientific understanding. It helps them transition to their Air Force leadership roles which require a high degree of initiative and ingenuity," said Ward. "Faculty researchers are able to update the curriculum to include the latest ideas and concepts in their fields. Furthermore, they set a positive example for their students by tackling new intellectual challenges. Every problem set challenges the students to understand something new. Teaching requires understanding concepts and methods in greater depth than research, thus lesson preparation often leads to new insights that then lead to a research breakthrough. Faculty who make significant research contributions are therefore the most effective teachers while teaching faculty are also the most effective researchers, provided they find time to do both."

"USAF research centers performing cutting-edge research are vital to the ability of the United States to remain a science and technology world leader in the decades to come," concluded Ward.





“We don’t just find better ways to teach physics.... we find better ways to teach students how to learn.”

*— Lt Col Steven Novotny
CPER Director*

CENTER FOR PHYSICS EDUCATION RESEARCH

Empowered Faculty Results In Inspired Students

In 1994, the Academy Center for Physics Education Research (CPER) was formed by Professors Evelyn Patterson and Gregor Novak to build what is a center of gravity for the Academy; providing impetus, opportunities, and tools for physics faculty to engage in and apply. This process is what later became known as the Scholarship of Teaching and Learning (SoTL) and is a large proponent for the center achieving their objectives. The center’s objective is to connect course and curriculum development with pedagogical research. CPER engages faculty and cadets in research initiatives that quantify gains

in student understanding and appreciation of physics, also empowering faculty by developing and sharing tools for enhancing teaching and student learning. “We don’t just find better ways to teach physics....we find better ways to teach students how to learn” said Lt Col Steven Novotny.

Recent developments have taken place with the Just-in-Time Teaching program (JiT), developed by combining a collaborative learning environment with extensive use of the world wide web. Active learner assignments and enrichment materials are delivered to the students over the web. During the 2009-2010

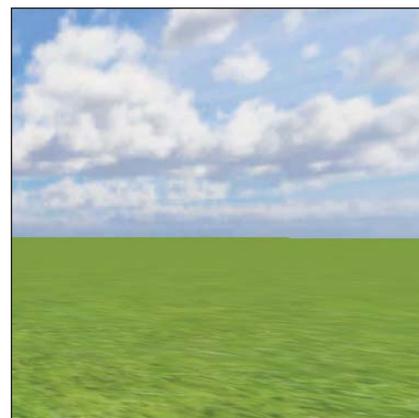
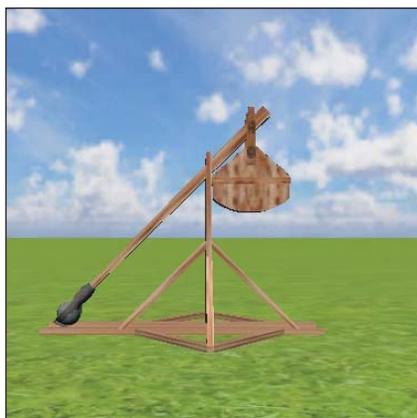
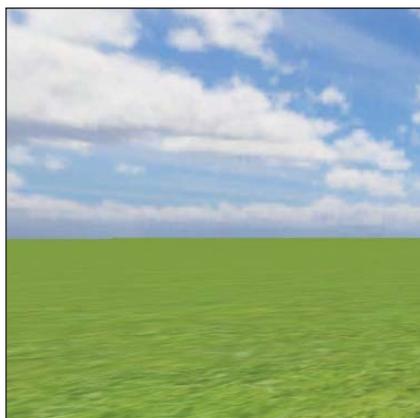
Academic Year (AY), the center expanded the JiTT-based curriculum to incorporate all core physics classes, spanning 50 sections and serving over one thousand students per year. The JiTT PreFlight Server is currently used by 2,400 cadets in 32 classes at USAFA and universities nationwide. According to Novotny, JiTT is the center's "most successful project to date."

Currently, CPER is collaborating with the United States Military Academy (USMA), NASA, and six civilian schools to complete a Do-It-Yourself Modeling project under a prestigious National Science Foundation grant. The project, driven by Dr. Gregor Novak, Dr. Brian Patterson, and Dr. Jim Rolf, requires cadets to develop interactive simulations, called D-I-Y (Do It Yourself) Modeling, and learning models of Xbox-gaming quality. A pilot program was launched in Physics and Mathematics Honor's courses and is currently using physics and mathematics to build a trebuchet, a medieval siege device. To complete this task cadets use NASA simulation tools to assist in mathematical and physical modeling. During the construction process, cadets will retrieve all the necessary materials even if they have to go chop down a tree! Games have been designed for blending simulations into the classroom to enhance Science Technology Engineering Mathematics (STEM) learning in courses nationwide. The center looks forward to implementation of this kind in other universities nationwide during 2010/2011. "This is a forerunner of a much larger national effort to more fully engage (and recruit) students in STEM disciplines," said Novak.

Also in coordination with the physics education research group at the University of Colorado at Boulder (CU Boulder), CPER is formulating new tools for educational success. Utilizing this partnership, CPER is developing and testing classroom tutorials for upper division physics courses. The physics education group at CU Boulder was founded by Carl Weimann, a 2001 Nobel Prize winner. "The group and Dr. Weimann have strongly supported CPER in its efforts" said Novotny.

CPER has worked to develop strong relationships with other universities, but the contribution within the Air Force from the center must be noted. In extending the focus to aid the broader operational Air Force, CPER has collaborated with Air Force's 1st Weather Group. The collaboration involves the center-implemented plans to lead workshops to properly equip trainers to become better educators.

Faculty involvement has provided immense contributions to the center's successes. Dr. Novak and Dr. Evelyn Patterson authored the leading chapter in the book *Just in Time Teaching Across the Disciplines and Across the Academy* (Nov. 2009). Dr. Novak plans to contribute a chapter to the upcoming volume of Jossey-Bass's *New Directions in Teaching and Learning* (Summer 2011). This year Dr. Novak was invited to lead two workshops on JiTT at the Commission on Colleges of the Southern Association of Colleges and Schools Institute on Quality Enhancement and Accreditation in Tampa, Florida.





“SoTL is a way for us to enrich cadet learning by linking our new approaches to published good practices, to collect data on the effectiveness of those approaches, and to share the findings with our colleagues.”

— Dr. Lauren Scharff
Director SoTL

SCHOLARSHIP OF TEACHING AND LEARNING

Understanding Perceptions Key Element of Education

The Scholarship of Teaching and Learning (SoTL) represents a growing national and international professional movement that recognizes, publicizes, funds and advocates the scholarly approach to understanding factors that impact student learning. These factors include specific teaching techniques, incorporation of technology, organization of materials, use of group work, etc.

Funded by a generous gift from Mr. John Martinson, which funds many of SoTL projects and events, the SoTL program’s efforts energize on-going USAFA education initiatives and create a fertile environment for new ideas. The

research results of SoTL projects directly benefit cadets and faculty across the Academy.

“SoTL is a way for us to enrich cadet learning by linking our new approaches to published good practices, to collect data on the effectiveness of those approaches, and to share the findings with our colleagues,” said SoTL director Dr. Lauren Scharff. Because no two learning environments or instructors are exactly alike, the research efforts contribute to a library of best practices for instructors from across disciplines to learn from and apply to their toolbox of teaching techniques.

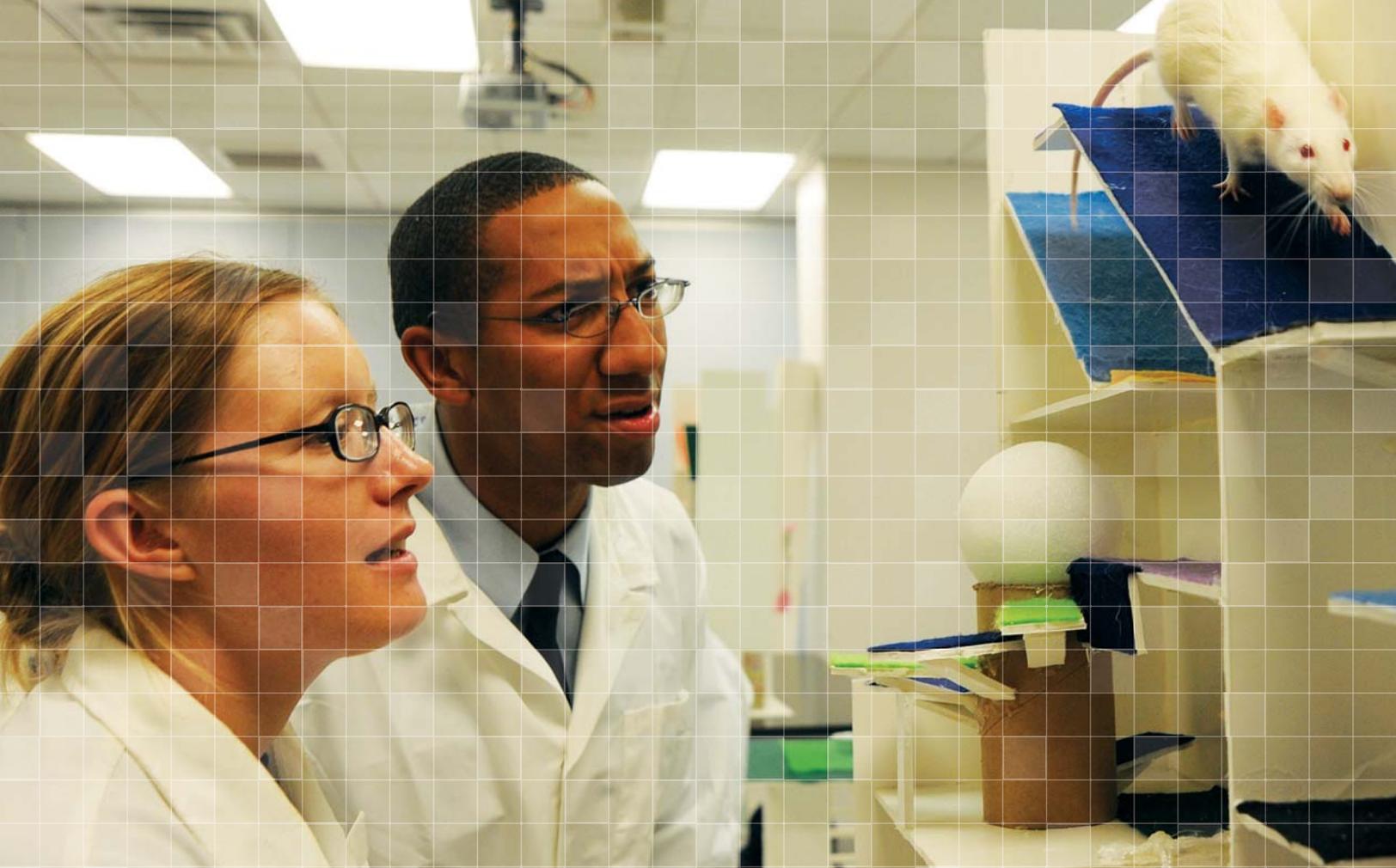
During the 2009/2010 academic year, 11 SoTL research projects were implemented. These projects involved faculty from twelve departments and programs, across all four academic divisions. For example, Department of Computer Science instructor Dr. Dino Schweitzer created a series of online computer graphics tools to investigate how the use of those tools would enhance learning of the related course material. The Department of Political Science investigated the impact of writing and discussion activities designed to promote critical thinking and a deeper understanding of American Politics. An Engineering Mechanics project studied influence of the time between initial learning of content material (e.g. initial presentation in lecture) and later use of that material (e.g. homework problems) on the long-term retention of that material. A multi-disciplinary project analyzed cadet and instructor perceptions regarding the use of pre-class assignments in several core courses and factors that mediated assignment completion rates. SoTL projects also reach beyond the traditional classroom, such as a project to

implement and assess a new training module at the winter Cadet Commanders Leadership Enrichment Seminar (CLES).

Beyond promoting research, the SoTL program also provides support services for faculty members. Speaker events and workshops bring together Academy faculty and external SoTL researchers. SoTL Circles is another way the SoTL program contributes to faculty development and, more critically, to the cadets' educational growth and success. These hour-long meetings offer faculty the opportunity to exchange ideas related to the broader subject of teaching and learning and to the exploration of applying those ideas to the scholarship of teaching and learning..

"SoTL supports our mission to develop leaders of character by allowing us to evaluate cadet learning, whether or not it's in the traditional academic classroom, and to apply what we learn in order to continuously improve what we do. This is "real world" research and our cadets and faculty are the direct beneficiaries," said Scharff.





SOCIAL SCIENCES AND HUMANITIES

Classical Education = Well-Developed Leaders

Directly impacting the future of our cadets is their ability to integrate the Social Sciences and Humanities into their decision-making and leadership processes. The importance of studying areas like Political Science, Oral History, Law, and Foreign Language remains a priority as demonstrated by numerous projects in 2010. Col James Durant, Deputy Department Head and Professor of Law, illustrates this importance, "We give them the building blocks to make the right decision that will ensure good order and discipline... this is fundamental to leadership."

The Center for Oral History is the latest addition to USAFA's humanities research. It is sponsored by Academy Superintendent Lt Gen Mike Gould and directed by Dr. Bob Wettemann. According to Dr. Wettemann, the purpose of research in this center is to "preserve spoken memories, perceptions,

and experiences of individuals relating to the history of USAFA, its graduates (especially combat veterans), faculty, athletic members and others with value to the heritage of the Air Force." The Center for Oral History will provide a long-needed resource; Dr. Wettemann intends for "nothing less than the premier and comprehensive Center for Oral History anywhere in the world."

Another accomplishment benefitting cadets' humanities awareness includes the Foreign Language Department. Colonel Daniel Uribe, Department Head of Foreign Language, said that all languages taught are on the Strategic Language List published annually by the DoD. Uribe explains that USAFA has defined strategic as those languages that are less commonly taught." There are eight languages offered including Arabic, Russian, Chinese, Portuguese, Japanese, Spanish, French and

German. Cadets are provided opportunities to travel to foreign countries through the Olmstead Program. The Language Immersion Program, offered by the Foreign Language Department, provides cadets with overseas experiences to build language skills and inter-cultural competence. About 30 percent of cadets graduated with a foreign language minor in 2010.

Research from the Department of Political Science directly affects USAFA's mission. Dr. Damon Coletta, a professor in the Department of Political Science, explained, "[Research]...keeps our faculty sharp for creating new syllabi and updating the staple courses and grows the national reputation of our department."

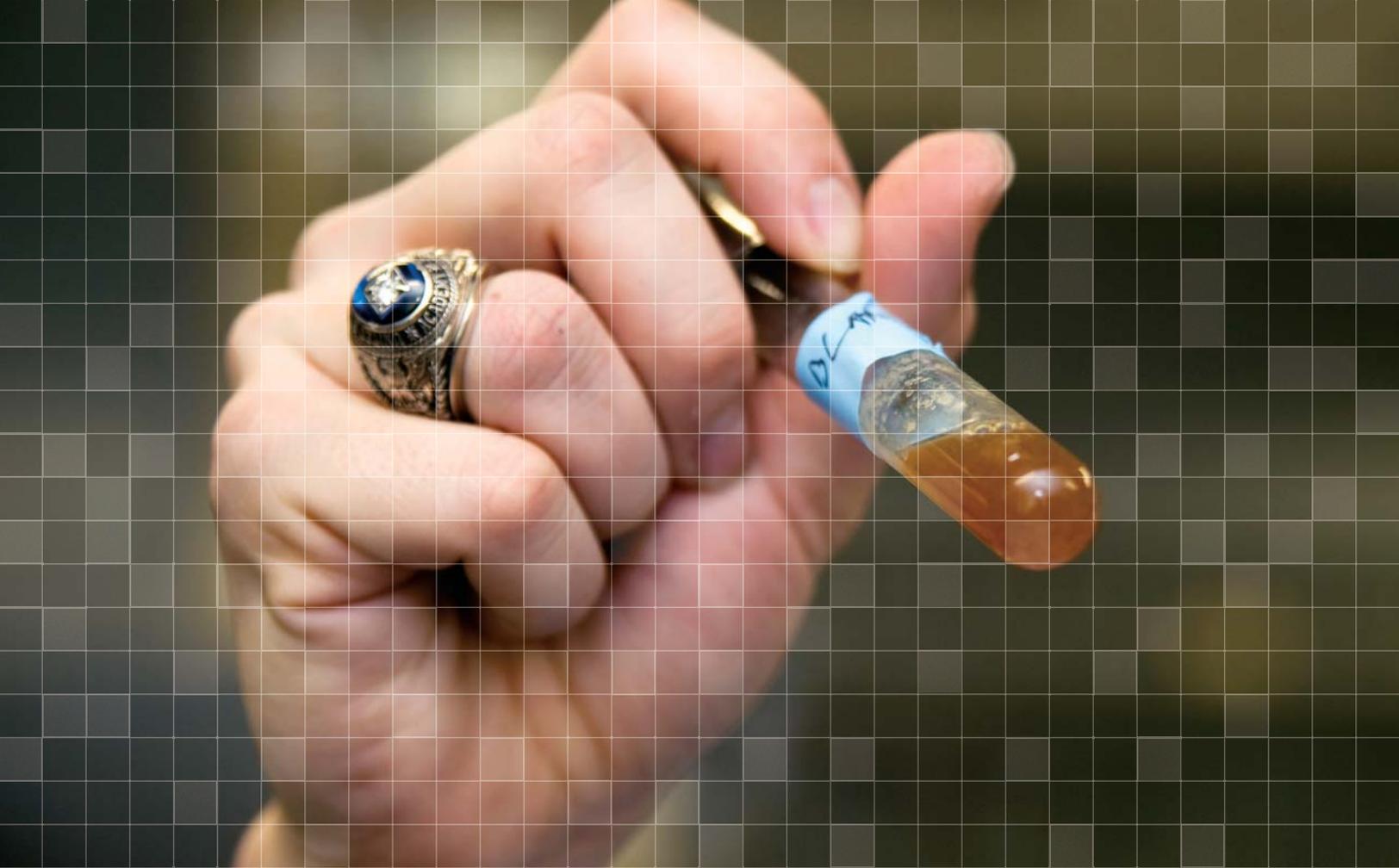
Col Cheryl Kearney, Head of DFPS, also noted the growing national reputation of the department characterized by the joint projects with sister academies like West Point. According to Kearney, her department's research is invaluable as it "contributes to the national discourse on issues of high politics such as the Constitutional basis of our grand strategy, the current condition of U.S. civil-military relations, the political development of other nations, the role of international law in stopping genocide, and the national security threat posed by violent non-state actors." The Eisenhower Center for Space and Defense Studies, housed within the department, allows for the department to support Track II diplomacy and produce real-world analysis of space policy that reaches the highest levels of government.

Political Science projects this year also have implications for science and technology education, including application towards the challenges of principal-agent (doctor-patient, lawyer-client, military-civilian) relations to the

interaction between American government and the scientific community. "It makes the case that greater emphasis on science as a profession with social responsibility during the education process would allow for more autonomy of the scientist" said Coletta.

History, Foreign Language, Economics & Geosciences, and Political Science departments have partnered to produce a human terrain analysis for AFRICOM. The project includes information on the region's history, geography, and other topics of potential intelligence use for the command. Worthy of note, also from the Department of Political Science, is the work of Dr. Frances Pilch who co-authored, "Superbugs: Resurgent and Emerging Diseases and Pandemics: A National Security Perspective." Pilch worked across disciplines with co-author, 2nd Lt. Ken Gosselin, supplying the mathematical modeling and Pilch contributing the social science research.



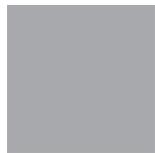


CADET SUMMER RESEARCH PROGRAM & COLLABORATIONS

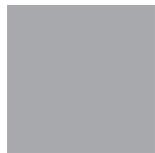
Demand for Cadets' Innovation Continues to Drive Summer Research Opportunities



There is no substitute for on-the-job, real-world training and research. The Academy's Cadet Summer Research Program (CSRP) ensures that every cadet wanting to contribute to Air Force mission-critical research is given the opportunity to make a difference.



This unique undergraduate research effort has evolved to become a linchpin in the Academy's learning-focused mission. Every summer, rising first class cadets are paired with various research projects throughout the Department of Defense, the federal laboratories, other institutions of higher learning, and with a diverse group of private



commercial companies and DoD contractors - often giving up their own personal time for the three to five week long program. Historically, cadets participating in CSRP research projects have produced award-winning graduate-level, or higher, results for customers and often continue their research during their first class year as independent study projects.

Cadets who achieved significant research success during their CSRP project also have the opportunity to compete for the Academy's Thomas D. Moore Outstanding Cadet in Summer Research awards, which honor cadet research in the social sciences, humanities,

engineering, basic sciences, and overall research. The winners of these awards are recognized at an annual award ceremony.

Examples of some recent CSRP projects include summer research programs investigating alternative energy production. Cadet Joel Primm worked with Dr Juergen Polle, Brooklyn College, NYC, a foremost authority on screening/isolating microalgae for use as feedstocks in biofuels. Primm learned novel high-throughput biochemical techniques for identifying microalgae with high oils content necessary for biofuels production. Another cadet, Travis Lyon traveled to Wright-Patterson AFB (AFRL/RXSC), where he worked side-by-side with AFRL academic partner, University of Dayton research personnel, in producing large quantities of microalgae stocks using experimental photobioreactors. While there, he evaluated methods (environmental manipulation) critical to increasing microalgae yields in commercial-scale photobioreactor units. Both young men gained a wealth of knowledge that will be essential to our continuing work involving bioenergy in direct support of DoD, AF and USAFA alternative energy initiatives.

Currently led by Capt David Ratliff of the Department of Economics and Geosciences, the program sent almost 200 cadets to CSRP partners during the summer of 2010.

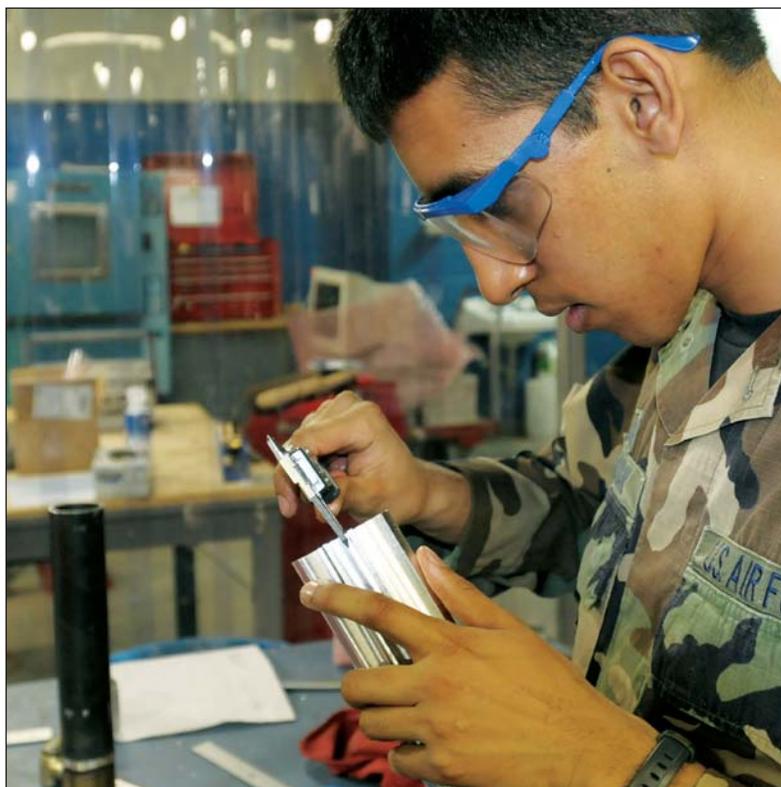
“When cadets go on CSRP, they see some of the world’s experts directly applying the principles from cadet classrooms. They use their skills and knowledge to contribute solutions to teams working on real-world problems,” said Ratliff.

Cooperative Research and Development Agreements (CRADAs) are a key aspect of both the CSRP program and the overall research program at the Academy. For every non-governmental research partnership with companies like Lockheed Martin, Raytheon, and Greenvolts as well as for institutions of higher learning

like the Colorado School of Mines and Georgetown University, there is a CRADA outlining the scope and goals of the joint research efforts. The USAFA research program grew in 2010 and currently manages more than 90 active CRADAs as well as many joint research agreements with federal entities including numerous Air Force bases, NORAD/ Northcom, the Air Force Office of Scientific Research, the United States Congress, the FBI, and the Naval Post Graduate School.

The Colorado Springs Undergraduate Research Forum, international officer-exchange programs, and large cadet study abroad and language immersion programs are other ways the Academy works cooperatively with local, national and international governments, organizations, and corporations.

As an educator, Ratliff stresses the intrinsic as well as realistic benefits of the CSRP program. “This exposure expands cadets’ vision and increases their motivation to master academic and leadership principles.”





“By encouraging proven educational organizations to work together, the big winners will be the students.”

*—Vivian Teets
CCESSE board member*

SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS

When I Grow Up...

We can all remember a time in childhood when something clicked inside and we were on fire- our minds and our hearts knew what it was we were meant to do when we “grew up.” There is something to be said when you witness that moment up close in the eyes of a child, that moment when a child, watching a rocket take off, states with innocent wonder and child-like determination - “I am going to build rockets when I grow up.”

That split-second moment in time is the catalyst behind the Academy’s Science, Technology, Engineering and Mathematics (STEM) outreach efforts. There is a dire future facing our nation’s corps of scientists, engineers, mathematicians and technologists. Simply put, if the education and career trends of today continue, there will not be enough Americans in these fields for the technology,

science, and defense needs of our future. Rising to meet the call of the President of the United States and the Department of Defense, the Academy has initiated a multi-disciplinary and multi-pronged approach to addressing the STEM needs of the nation and the local Southern Colorado region.

The Department of Aeronautics, led by Col Neil Barlow, hosts an annual educator summer seminar workshop and provides hands-on learning opportunities for teachers to take back into their classrooms. The department also welcomes elementary, middle, and high school students from across the region to tour their labs and participate in workshops and seminars.

Within the Astronautics Department, faculty instructors have organized countless tours for hundreds of students over the past academic year. Students are treated to videos, tours of

the FalconSat ground operations center and the small museum that houses the FalconSat and FalconLaunch models as well as other space systems related artifacts. The department also supports the Academy's Summer Seminar program for high school students interested in pursuing STEM majors in college.

There are several organized STEM efforts within the Physics Department that are reaching out beyond the walls of Fairchild Hall and into the community at large. Through programs like Physics is Phun, Girls in the Middle, and STEM at the Observatory every year, thousands of students are exposed to and offered opportunities to explore science, astronomy, and physics. Physics is Phun has visited dozens of schools and classrooms regionally, Girls in the Middle has reached middle school girls across the Southern Colorado region and has offered them learning and networking opportunities around the country, and STEM at the Observatory has brought hundreds of students, Girl Scouts and Boy Scouts troops to the Academy Observatory to work with cadets and local astronomy clubs and to learn about the solar system and our broader space mission.

The Department of Chemistry, led by Col Mike Van Valkenburg, has reached thousands of students, teachers, and STEM professionals working across the Department of Defense. Working with many local area non-profits,

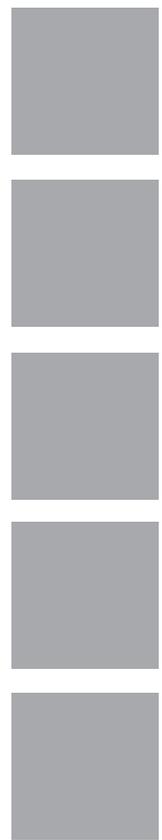


such as CoolScience and the Girl Scouts of Colorado, the Department of Chemistry exposes students of all ages and experiences to the basics of engineering, chemistry, rocket science, mathematics, physics, and more. Activities such as the Chemistry Magic Show, "Bungee" Barbie®, and Fun with Acids and Bases create fun, multi-disciplinary challenges for the students. Adults who are treated to the Chemistry Magic Show are reminded of the wonder of science and their desire to understand the world around them.

As part of the broad national effort to address the nation's STEM needs, the Academy's Office of the Chief Scientist and Director of Research obtained grants authority in 2010 and working with the Office of the Secretary of Defense's National Defense Education Program (NDEP), provided a grant of \$215,000 to the Colorado Consortium for Earth and Space Science Education (CCESSE).

Comprised of several regional education and non-profit STEM organizations including the Challenger Learning Center of Colorado, Project Lead the Way, CoolScience, and the University of Colorado at Colorado Springs, CCESSE is leveraging this grant to provide teacher education workshops such as the three-day Space Technology Applications Reaching Students (STARS) and the first Academy STEM Boot Camps, provide scholarships to students to participate in regional STEM education activities such as the Challenger Learning Center of Colorado's summer camps and school-year missions, and to provide funds to maintain CoolScience programming opportunities. "By encouraging proven educational organizations to work together, the big winners will be the students," said CCESSE board member Vivian Teets.

The Academy, with its decades of building our nation's STEM professionals and Air Force leaders, stands ready to expand its role in this national and regional STEM education issue. We are looking for and investing in regional STEM solutions that will offer valuable lessons and a path forward for other communities across the country.





INSTITUTE FOR INFORMATION TECHNOLOGY APPLICATIONS

Enhancing Airman Readiness

It is not enough to have current information technologies. By producing leading edge, operational information technology, the Institute for Information Technology Applications (IITA) works to provide tomorrow's Air Force next generation information technology systems.

Led by retired General James P. McCarthy, the institute reflects a respect for the lessons of the past with an eye towards the future. As the father of the Academy's cadet soaring program, McCarthy is no stranger to implementing innovative technologies. Today IITA is leading the way on several cutting-

edge Air Force information technologies. He recently emphasized the importance of involving cadets in these developments.

"One of IITA's top priorities is to provide cadets the opportunity to develop real-world, operational military systems," said McCarthy. "Cadets are in the classroom developing software that will go into a system in six months time, which will be used by pilots, flight commanders, and eventually, the whole Air Force."

The Warfighter's Edge (WEEdge) project is the main project of the institute. The stable and

robust WEdge application provides Air Force pilots real-time, mission essential briefings in minutes and utilizes a common Windows-operating system. In less than three years, the program has gone from the drawing board to approval for Air Force-wide operations. The program is currently deployed to more than 10 bases. According to the director of the WEdge project, Lt Col Andrew Berry, cadets are involved in multiple WEdge areas of research and development including a digital aeronautical flight information plug-in, 3D viewing capabilities capable of interfacing with Google Earth, and a joint mission planning software to collaborate mission planning throughout the DoD.

The Joint Installation Picture 4 Command & Control (JIP4C2) is another on-going project to provide critical event information to military and first responders including police, fire, and ambulance personnel. The project utilizes global positioning satellite and wireless communications technologies and has been deployed throughout the Air National Guard (ANG).

IITA's Ms. Carolyn Dull mentors a team of Wing IT Services Engineers (WISE) who are challenged by General (ret.) McCarthy to



determine important ways that information technology (IT) can improve the Cadet Wing. One of the projects from this year was the development of a Cadet Command Center automated bugle call system that eliminates human interface errors, such as the of playing "Taps" instead of "Reveille." Another project that the WISE cadets accomplished was an automated BAS form that allows cadet TDY reimbursements to flow more efficiently. As a final sample of the WISE team's abilities, an energy efficiency project has been researched and proposed to USAFA leadership and is expected to save USAFA \$40,000+ a year in energy usage.

The "Airdrop Enhanced Logistics Visibility Information System (AELVIS)" project will develop software to track airdropped resupply bundles and their contents from command centers or ground forces worldwide. This will enable accurate and timely decision-making, will save money, and assist in the locating of lost items. Engineering Mechanics cadets will be involved in the "hardening" of the project's proposed tracking device.

"One of the principle missions of the Air Force and therefore the Academy is flight operations. We are highly motivated to develop that capability and the understanding of the precise discipline needed to support operations," said McCarthy on the challenge of simultaneously developing cadets and the new technologies needed by the Air Force. He added that the level of cadet participation in IITA projects results in highly motivated cadets who eventually will move into wing organizations and command and control positions. To help better prepare cadets for their future roles as officers, McCarthy has initiated an effort to identify and develop information technology capabilities specific to the cadet wing's needs.





INSTITUTE FOR NATIONAL SECURITY STUDIES

Developing Strategic Expertise

In April 2009 the United States committed to a course that continued the 50-year tradition of arms controls and balanced strategic weapons reductions while also elevating non-traditional strategic threats and proliferation concerns to the very top of the policy agenda. A year later a New START Treaty was negotiated with Russia, a Nuclear Posture Review provided policy and strategy guidance, and the United States hosted a Nuclear Security Summit seeking international cooperation to secure nuclear weapons and materials globally within four years. Strategic issues, and specifically nuclear issues, had clearly taken a central place on the policy agenda.

The Air Force Institute for National Security Studies (INSS) has focused research, published reports, and developed leaders with strategic knowledge and perspective for

18 years, and it is well-positioned to continue to support Air Force and DoD involvement in these national priority areas. Housed within the faculty at USAFA, INSS reaches out across that faculty and the broader military academic community to conduct research and to bridge the academic, think tank, and government policy communities on strategic issues. Led by Dr. Jim Smith since 1998, the INSS mission is to guide research on strategic, enduring, and emerging national security issues, and to provide outreach through publications and workshops to convey the lessons of that research. But it also seeks to develop policy knowledge and analytical skills to help build military officers, and faculty that educate them, with enhanced knowledge and skills.

In addition to strategic topics, INSS research emphasizes other emerging issues,

“As the global strategic landscape continues to change, and as the USAF and DoD adapt to new operational demands that often overshadow enduring strategic interests and requirements, it is ever more important to maintain and advance strategic thinking and a pool of strategic expertise. INSS continues to focus on contributing in a small way to that end.”

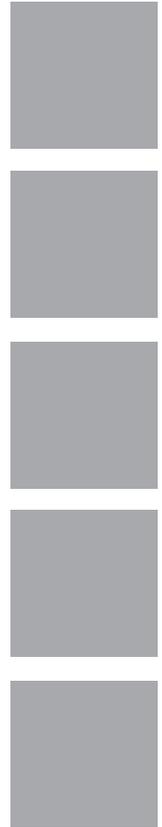
*—Dr. Jim Smith
Director, INSS*

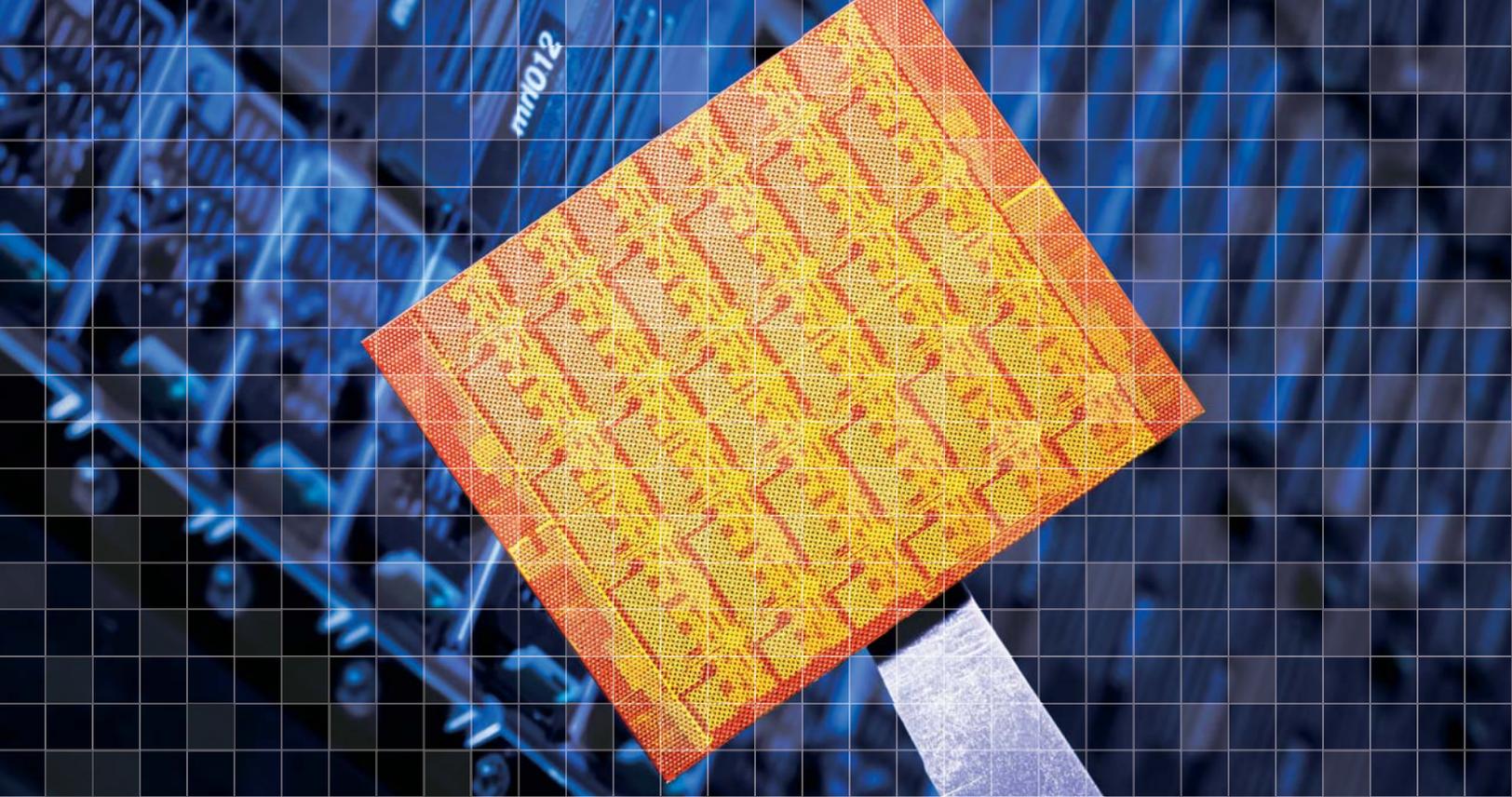
environmental security and sustainability, and the changing face of Twenty-First Century conflict with special emphasis on implications for air, space, and cyber forces

and requirements. INSS also publishes policy papers and supports and contributes to texts to further expand the outreach and education effort.

Faculty researchers are strongly encouraged to include cadets in their projects in mentored roles, and to incorporate their own work directly into their classrooms to ensure relevance and currency. This year INSS instituted a Strategic Summer Seminar, bringing 12 hand-picked military and civilian doctoral students and recent recipients to USAFA for a one-week immersion on a strategic issue: this year proliferation. For the next year, INSS will focus on new and adapted concepts of strategic stability, biosecurity threats, enhanced strategic education for the Air Force, concepts of limited nuclear war, and arms control compliance and verification.

“As the global strategic landscape continues to change, and as the USAF and DoD adapt to new operational demands that often overshadow enduring strategic interests and requirements, it is ever more important to maintain and advance strategic thinking and a pool of strategic expertise. INSS continues to focus on contributing in a small way to that end,” Smith said.





ACADEMY CENTER OF INNOVATION

Adapting today's networks for tomorrow's needs



The naturally evolving nature of warfare makes it the responsibility of the United States Armed Forces to lead the advance by teaching tomorrow's military leaders the tenets of creativity and innovation as they apply to products and processes.



In order to foster these capabilities, the Center of Innovation (Col) merges leading-edge private industry research with Federal Government demands, and places cadets in front-line research to foster the next generation of DoD capabilities. The Col then utilizes leading-edge private industry technologies and the cadets' web 2.0 skill sets in the Rare Event Games, where novel technologies are field tested in a social collaboration experiment.



The Col's Rare Event Games, simply put, are social collaboration experiments run on test networks. Rare Event Game participants from service academies utilize social collaboration concepts to predict and prevent a 'rare event', such as 9/11 or the Fort Hood massacre. Lack of information sharing and collaboration has been widely identified as a weakness in



our nation's defense capability. In the wake of the Detroit terrorist incident on 25 December, President Obama expressed his concern that our intelligence agencies are not properly "Connecting the Dots" to predict future terrorist attacks. Addressing this capability gap, the Col is persistently driving toward a solution by harnessing the power of the social networking cadet generation, and using that power in new and creative operating processes. The Rare Event Game will also field test innovative technologies still in Intel Corp and Cisco R&D to create a novel computer network, the Mission Fabric Network. Described as a system of systems, the Mission Fabric Network is designed to utilize social network paradigms to place intelligence at the node-level to enhance distributed collaboration and ad hoc group action to create a single complex adaptive system.



The Col has aggressively pursued relationships with the most innovative private enterprise organizations to provide unprecedented educational opportunities to cadets and notable innovations to the

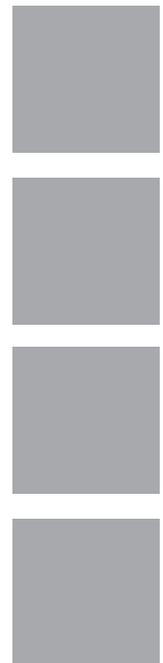
Federal Government. In the spring of 2009, Intel Corporation signed a Non-Disclosure Agreement (NDA) which allows the Col and the Federal Government to view, for the first time, the 171 projects in Intel's \$6.2 Billion R&D portfolio. With the positive cascading effects this agreement has elicited, the Center of Innovation has secured an NDA with Cisco Systems, and commenced relationships with the National University of Ireland's Innovation Value Institute (IVI) and IBM's Watson Center.

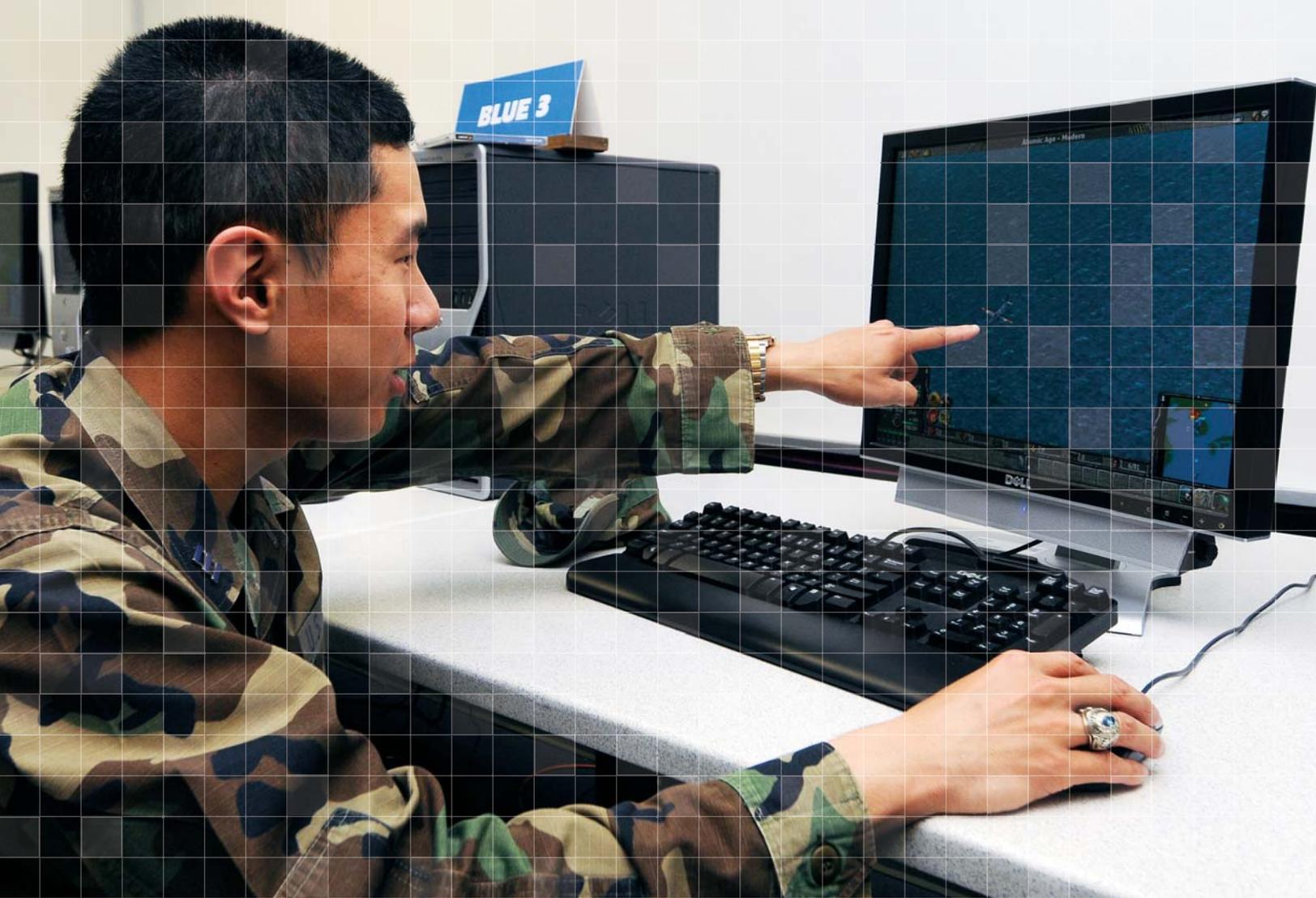
"The Col firmly believes that today's cadets are the key to championing innovations for tomorrow's challenges," Dr. Terry Pierce states. "To foster an innovative culture, the Col actively seeks out leading-edge innovative researchers who will mentor cadets on their research projects. For example, having a cadet conduct research with Intel Corporation researchers on Intel's advanced 48-core chip was a first for both Intel Corporation and USAFA. These unique opportunities are critical in cultivating an innovative culture among tomorrow's Air Force leaders."

Cadet involvement is a prerequisite for every Col relationship, enabling cadets to enjoy unprecedented opportunities by conducting research with the R&D departments of private industry's most innovative companies. During the summer of 2010, two cadets worked alongside Intel Researchers in Hillsboro Oregon as part of the Cadet Summer Research Program (CSRP). C1C David Ryan participated in research and assisted in the design of the next generation of Intel Corporation's microprocessor chip, the Single-chip Cloud Computer, which will not be available commercially for another five years. C1C Kyle Warner (USCGA exchange cadet) assisted researchers in creating *paraverse*, a way to use GPS information to link physical movement in the real world to an avatar's movement at the same location in the virtual world. This capability is critical to access real world positioning and incorporate that data into the virtual world. Both cadets continued their research efforts back at the academies during the 2010/2011 academic year.

The Center of Innovation does more than simply place cadets in applied research, however. It

also utilizes ongoing relationships to place cadets in innovative organizations such as the Innovation Value Institute (IVI). During the 2010 academic year, three cadets from the class of 2010 worked closely with IVI, a Maynooth, Ireland-based consortium including 50+ organizations such as the National University of Ireland, Intel Corporation, and Boston Consulting Group. After receiving instruction in Ireland, the cadets helped develop the Intellectual Capital Management (ICM) method which enables companies to better recognize, classify, generate, maintain, register, deploy, and protect intellectual assets. ICM is part of IVI's IT Capability Maturity Framework, which assists companies (or government agencies) in building a business case for innovation in Information Technology. In the summer of 2010, the Col sponsored a Political Science/Legal Studies major to work directly with one of IVI's executive staff, to initiate a case study on the politics of innovation, and apply this study to federal government use. The Center of Innovation also hosts several Independent Study cadets during the academic year who receive innovation instruction from Col Director, Dr. Pierce, and represent USAFA in the Rare Event Game. These independent study cadets also help frame the future by conducting research, such as visiting the Harvard Center for Decision Analysis and researching Voice over Internet Protocol (VoIP) technologies for their applicability to warfighter and first-responder use.





ACADEMY CENTER FOR CYBERSPACE RESEARCH

Cyber Readiness Critical for Mission Success

When Google announced it was withdrawing from China over cyber-espionage, the spotlight was directed once again to the issue of our nation's corporate and national defense organizations' cyber security. The mission of the Academy Center for Cyberspace Research (ACCR) is to enhance cadet education through research in the domain of cyberspace.

"Cyberspace is an especially critical field for the Air Force today as new threats are emerging, the technology is constantly changing, and our mission and tactics in this domain are being developed," said ACCR

Director, Dr. Dino Schweitzer. "We provide cadets research experience critical to their development as students, Computer Scientists, and future Air Force officers."

One of the standout ACCR projects during the 2009/2010 academic year was a partnership with Regis University to develop a publicly accessible repository for computer security education tools. The center also hosted the annual Computer And Network Vulnerability Assessment Simulation (CANVAS) for schools along Colorado's Front Range. This one-day event featured over 75 students and faculty from 12 area colleges and

"We provide cadets research experience critical to their development as students, Computer Scientists, and future Air Force officers."

—Dr. Dino Schweitzer

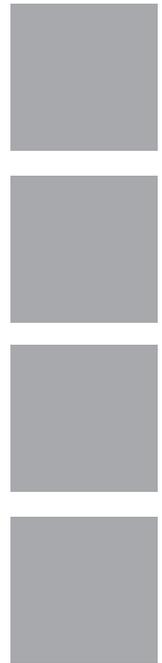
universities, including a group from Fort Hayes, Kansas. In addition, for the first time this year, a small number of local high school students were included to reach out to a broader audience. The purpose of the event is to enhance student awareness of the latest cyberthreats by having them evaluate a system for vulnerabilities using "hacking" tools and reporting discovered problems and recommended fixes. This year's scenario for evaluation was a locally developed social networking site mimicking popular sites. Rather than make the event a competition where schools compete against each other, teams are composed of students from different schools, which teaches students a valuable lesson in working with others with different experiential and academic backgrounds. At the end of an intense day of working on the computer, teams write up their findings in a report and submit them for evaluation. The top teams are recognized for their performance and awarded prizes. Faculty and students alike highly rate the experience as both informative and fun. Next year's event will be hosted by Regis University in Denver.

ACCR made numerous research advances as well. Dr. Leemon Baird's ground-breaking work in jam-resistant communications technologies has led to new algorithms, proofs, and development for hardware implementation. Baird's work was successfully demonstrated at the DoD Black Dart jamming exercise. A combined cadet and faculty research project on detecting keyboard patterns for breaking passwords was nominated as the best paper at the annual Visualization in Security VizSec conference.

Schweitzer said providing cadets a meaningful research experience is important to their development as students, computer scientists, and as future Air Force officers.

Cyberspace has become a mission-critical field not only for the Air Force but also for the nation as new threats continue to emerge and technology is constantly evolving. This environment makes it ripe for challenging research topics for faculty and cadets. Computer science majors are required to participate in a cyberspace research project and are paired with a faculty mentor. Top cadet projects are directed towards conference publications and presentations so that ultimately, cadet research for ACCR is at the forefront of the Air Force cyber mission and in the development of proactive and reactive tactics.

"Cyberspace is a broad field critical to the security of the nation as evidenced by the updated Air Force mission statement," Schweitzer said. "Cyberspace threat awareness goes beyond just computer scientists and affects all of us."





ACADEMY CENTER FOR UNMANNED AIRCRAFT SYSTEMS RESEARCH

Leading the Way for Tomorrow's RPA Pilots

The ability of the Air Force to provide timely, integrated intelligence, surveillance, and reconnaissance (ISR) to Department of Defense assets has become crucial to mission success and to saving lives.

The Academy Center for Unmanned Aircraft Systems Research (ACUASR) has been on the forefront of this call to action – having graduated its first class of RPA operators in 2010 and is leading ground-breaking research on a variety of new technologies including multiple, autonomous RPA operations, perching technologies, and intelligence gathering abilities.

The knowledge of ISR and their relationship to the development of the next generation of remotely piloted aircraft (RPA), formerly known as unmanned aerial vehicles (UAS), are crucial skills for today's operations and tomorrow's Air Force leaders. In 2010, the Air Force Posture Statement called for greater investment and deployment of RPA technologies and aircraft as well as for more RPA-only pilots and manpower hours dedicated to supporting RPA operations and ISR integration.

Led by Dr. Daniel Pack, the center is multi-disciplinary by nature, utilizing faculty and cadets from Aeronautics, Computer Science,

and Electrical and Computer Engineering. This unique facet offers complex classroom and research challenges to cadets and requires them to solve problems on a myriad of levels. "During the process I hear multiple times that the problem is too big, but at the end, they (cadets) see how much they have accomplished," said Pack. "They become more confident, stronger cadets, with a 'can do' attitude, leaders and officers."

The center does not shy away from seeking challenging, outside research projects. The ACUASR is currently working on research projects with a number of outside academic, government, and industry partners including the Office of the Secretary of Defense, Rapid Reaction Technology Office; the Office of the Secretary of Defense, Joint Improvised Explosive Device Defeat Organization; the Naval Surface Warfare Center; the Air Force Research Laboratory, Information Directorate; and the Air Force Tactical Exploitation of National Capabilities Office. The total external research funding received during the past academic year was \$880,000.

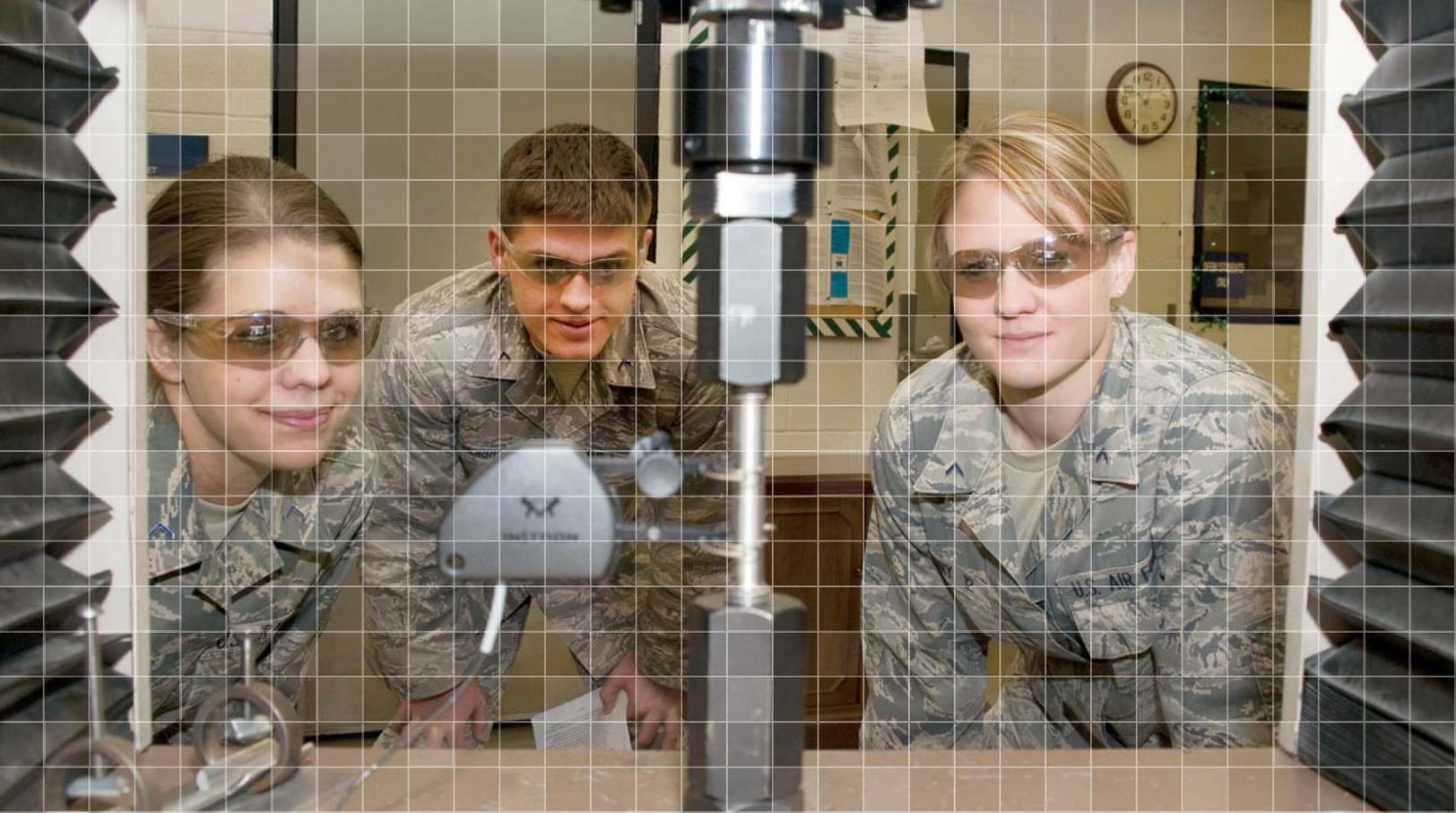
"Our research has shown that UAS operators have more information at their disposal compared to manned aircraft pilots. The operator's decision-making process depends heavily on critical thinking skills. That's why the USAFA emphasis on developing these skills as part of the core curriculum is so important," said Pack.

Ongoing research projects include the continued development of autonomous cooperative technologies for heterogeneous unmanned vehicles to perform wide-area surveillance and reconnaissance using heterogeneous sensors as well as to detect and track airborne chemicals. The ACUASR has expanded their research technologies supporting unmanned surface protection missions for the US Navy and to develop a red team unmanned aircraft system (UAS) that arms and detonates improvised explosive devices in an environment with jamming signals. During the 2009/2010 academic year, the center successfully demonstrated these capabilities through actual flight tests and simulations

in the case of the unmanned surface naval vessels.

As for cadets pursuing Air Force careers in RPA and unmanned technologies, Pack has no doubt about their futures. "It is clear from our experience in Iraq and Afghanistan that there is a bright future in the USAF for officers who understand the capabilities and employment of unmanned aircraft systems. Our efforts in the ACUASR help to prepare our faculty and cadets for this important responsibility before they leave the Academy."





CENTER FOR AIRCRAFT STRUCTURAL LIFE EXTENSION

Aging Structures Meets Fountain of Youth

When the KC-135 Stratotanker taxis down the runway, it is carrying more than 50 years of service history with it. First put into service in 1956, the Air Force has a fleet of 415 KC-135s, with the last one delivered in 1965. Making sure this aging workhorse is able to continue its missions across the globe is critical. That is where the Center for Aircraft Structural Life Extension (CAStLE) comes in.

The center's main mission is to provide structural integrity tools for the aerospace community, in particular to the aging fleets of the Air Force and Department of Defense.

One of the Center's main continuing projects from now and into the future is a joint KC-135 tear-down and analysis program with Tinker AFB and KC-X Acquisitions. CAStLE

researchers and mechanical engineering cadets are working with the latest technologies to examine how and where stresses occur in the structures and, if possible, devise new ways to quickly identify potential structural hazards in the field and apply new maintenance and repair techniques. These efforts will help extend the life of service for the fleet as well as help to identify cost-savings, best-practices for maintenance in the field, and improve safety. These discoveries can also have commercial aircraft applications, helping to save lives around the world.

The center's success in researching, identifying and providing life extension solutions has led to a variety of new projects and increases in funding. The center recently completed source selection on a \$90 million "Aging Structures" contract to support the current and future

needs of the aging aircraft community. CASTLE has also undertaken several collaborative projects to include Air Force Research Lab projects such as crack growth studies and a C-130 Center Wingbox Finite element model, a continuing project on C-130 Flight Data Acquisition and Analysis in support of the U.S. Coast Guard, and a six-member University Corrosion Collaboration with Ohio State University, University of Hawaii, University of Virginia, University of Akron, and the University of Mississippi. The project is expected to generate more than \$1 million in funding in 2010 and has attracted over \$12 million in external corrosion research. The research projects involved in the collaboration include energy harvesting, corrosion and stress corrosion cracking of aging aircraft, and corrosion preventive compounds.

"The essence of USAFA is what makes us ideal for research: brilliant faculty researchers, world-class facilities and equipment, enthusiastic and talented cadets, and an overall culture that stresses hands-on learning," said Engineering Mechanics Department Head and Permanent Professor Col Tom Yoder. "Research supporting DoD here at USAFA just flat out makes sense!"

For cadets, CASTLE is a professional and academic proving ground. Recent cadet-led projects include C1C, now Second Lieutenant, Erin Scott's research on crack growth in aircraft structures and an independent project researching fatigue and corrosion of aircraft structures led by C3C Jan Teope and Brittany Rucker. Scott's results were presented at the 2009 Aircraft Structural Integrity Program Conference as well as to Vice Chief of Staff of the Air Force General C. "Howie" Chandler.

CASTLE cadets also participated in the Service Academy Challenge, a senior design capstone, which pits USAFA against Army's West Point and Navy's Annapolis in a quick reaction tasking for real-world needs. This year, the challenge was to design a counter-sniper/counter-ambush remotely controlled aircraft or vehicle to support special operations forces in the field. The scenario used was based off the 1983 Panama

operation where Navy Seals were pinned down at an airfield and took significant casualties. The competition was held April 2010 at Ft Hood, Texas. For this competition, the CASTLE cadets presented a heavily modified convoy truck outfitted with day/night sensors and a modular array of weapons to find, fix, and neutralize enemy threats.

Ultimately, these professional research and academic opportunities are of immeasurable value to the Air Force. "There is absolutely no comparable substitute for the experience of a future Air Force acquisition professional meeting a customer, sorting through their mission, needs and desires and then digging into your undergraduate body of knowledge & skill, time and effort to provide them a solution to their problem. The event of providing a real-world user the product of your intellectual and physical efforts and defending it before GO/FO/SES level leaders is light years beyond the validation a cadet gets from a classroom report or exam grade!" said Yoder, whose department oversees CASTLE efforts. "The undergraduate experience, especially in engineering and sciences, requires a lot of fundamental knowledge to be laid at a foundational level; often leading the cadet to forget the passion and expectations that brought them into the discipline to begin with. Our partners & customers across DoD, the Air Force and the interagency provide our cadets with research, and independent learning and design opportunities that connect them directly to warfighters and operations with immediate needs, allowing the cadets to springboard off their classroom knowledge, season their innovative skills and feel both the professional satisfaction of success and the sobering





CHEMISTRY RESEARCH CENTER

Transforming Solar Energy

Significant advances in chemistry research have been emerging since the center was established, but the new USAFA Energy initiative provides a new stage on which the center's growing list of achievements can shine.

With the growing emphasis on the Net Zero Initiative – the USAFA goal of producing as much energy as it consumes – the Chemistry Research Center (CRC) will continue to push the boundaries of knowledge with cadet education as the driving force. "Cadet research brings it all together, accomplishing our mission," said Center Director Dr. John Wilkes. "Research brings you at the edge of knowledge, where you either stumble a little or build a bridge to the future."

With support from the Air Force Office of Scientific Research, the CRC continues to extend their bridge by making a wide range

of discoveries from neutralization of chemical agents for combating bio-warfare to the storage of hydrogen for fuel efficiency to the development of ionic liquids for transferring solar energy. The world-class research being produced by Chemistry's faculty and cadets has been recognized in peer-reviewed publications, recognition and awards at competitions and conferences.

One of the main research highlights of the 2009/2010 academic year was the discovery of a break-through solar thermal fluid. Researchers and cadets, in conjunction with Englewood, Colorado-based ZettaCore®, have discovered a new ionic liquid that will transform the solar technology field.

The new ionic heat transfer fluid is stable at any temperature from room to up to more than 400 degrees Celsius. This new compound



could be used as a heat transfer fluid in solar thermal technologies.

According to the Air Force Academy Chemistry Research Center director, Dr. John Wilkes, solar collectors utilized in parabolic troughs reach temperatures of 400 degrees Celsius or in layman's terms almost 800 degrees Fahrenheit. With this new ionic heat transfer fluid, the energy generated from solar thermal power can more effectively be moved from one place to another. "This new heat transfer fluid will allow solar projects to operate at a wide range of temperatures and it will increase solar and renewable energy flexibility. You can use it to pump stored heat at the start of the day when the sun comes up and the outside temperature is still cold," he said.

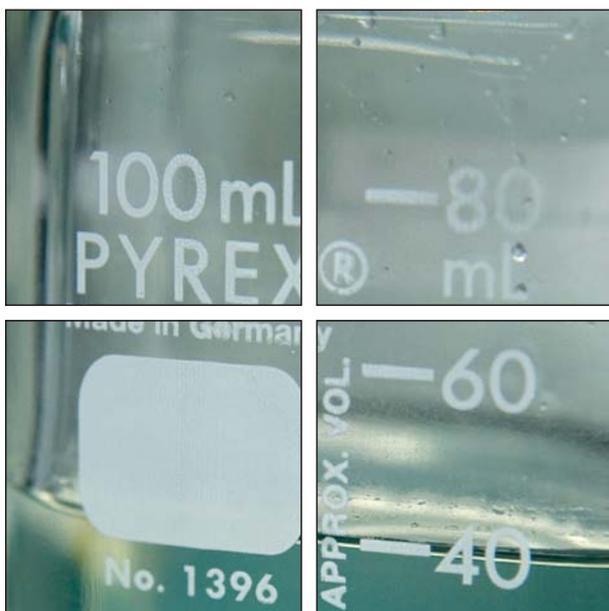
The discovery was serendipitous. Dr. Michael Krien, a German foreign exchange researcher at the Air Force Academy, was working with

Cadet 1st Class Christopher Ifft and Cadet 1st Class John Mark Campbell on a joint project for ZettaCore. The team discovered a series of 21 new compounds that have the potential to positively impact the solar industry. Through a Cooperative Research and Development Agreement, the Academy research team was working with ZettaCore on the use of ionic liquids for molecular memory applications. The company specializes in molecular materials including those for superconductors, molecular interface technology, and energy storage.

"This will be an excellent demonstration of this ionic liquid and a good adjunct to saving USAFA energy," said Wilkes.

Cadets are also involved in the growing search for efficient alternative energy sources, continuing to develop means of hydrogen storage, heat transferring properties of ionic liquids and the potential for utilizing solar power. In identifying and overcoming the properties of hydrogen that make storage difficult, researchers are working their way toward becoming adept in this process and harnessing this powerful source of energy. With the ability to efficiently and effectively store hydrogen, researchers will open the door for an abundance of alternative energy sources and further the green goals of the Academy, the Air Force, and the nation.

"Participation in research by students lets them go to the very edge of our knowledge – but they need an experienced guide," Wilkes said. "In education, the guides are mentors, where the teacher/ student ratio is one-to-one. This relationship is the main reason we do research at the Air Force Academy."





LIFE SCIENCES RESEARCH CENTER

Biofuel Will Strengthen National Security

The secret to solving our nation's future energy needs could potentially exist within a single-cell photosynthetic organism known as algae. The green slime found in salt, fresh, and even waste water throughout the world could tomorrow be fueling our cars and heating our homes.

Led by Dr. Don Veverka of the Department of Biology, the Academy's Life Sciences Research Center (LSRC) is working to further current research and to develop this promising energy alternative. Primarily funded by the Air Force Office of Scientific Research (AFOSR), the center aligns its research interests with AFOSR's Life Sciences interests to enhance cadet education and enable cadets to participate in cutting edge research.

In addition to its core funding from AFOSR, the LSRC received over \$300K in outside funding and had seven researchers from three different departments investigating biomimetics, altitude acclimatization effects, mild traumatic brain injuries, bio-detection measures, cadet health surveillance and algae to biofuels production.

"Cadet education with research is a vital pillar within the LSRC," said Veverka. "Every attempt is made to link research minded faculty with highly motivated cadet scientists. In the past year alone, we have had several cadets involved in a myriad of different projects connected with our sponsors. Many of these cadet researchers go on to present their work at national or regional undergraduate research conferences such as TriBeta Biological Honor Society, the Colorado-Wyoming Academy of Sciences and the American Association for the Advancement of Science."

Another linchpin in LSRC is the Cadet Summer Research Program which has grown tremendously. In 2010, LSRC sent 13 cadets to various institutions across the country. Among the center's usual government sponsors, cadets also took advantage of some outside sponsors such as the University of Cincinnati, Boeing, and Brooklyn College, which helped expand the cadet research experiences in human genetics, patient care/evacuation surgical techniques, human performance studies, biofuels development and biological tissues effects from directed

energy studies. This was also the second year that the Oklahoma Medical Research Foundation (OMRF) supported one of LSRC's cadets through the OMRF Presidential Scholar Program. Cadet Max Barnes was competitively selected to attend a month-long research project in the Biomedical Sciences, in Oklahoma City, Oklahoma. OMRF has an exceptional reputation as one of the country's oldest and most respected nonprofit biomedical research institutes.

The Boeing Corporation has also generously set up a cadet research endowment fund. This endowment will support cadets conducting joint research between Boeing and USAFA in areas involving pilot performance and cockpit design, and will include the efforts of several departments in collaboration. Air Force Research Laboratories (AFRL) also continue to generously support USAFA cadet research programs. For example, this past year, two LSRC cadets were funded by AFRL to investigate alternative energy production. Cadet Joel Primm worked with scientists at Brooklyn College, City University of New York learning novel high-throughput biochemical techniques for identifying microalgae with high oils content. Cadet Travis Lyon traveled to Wright-Patterson AFB (AFRL/RXSC), where he worked side-by-side with University of Dayton research

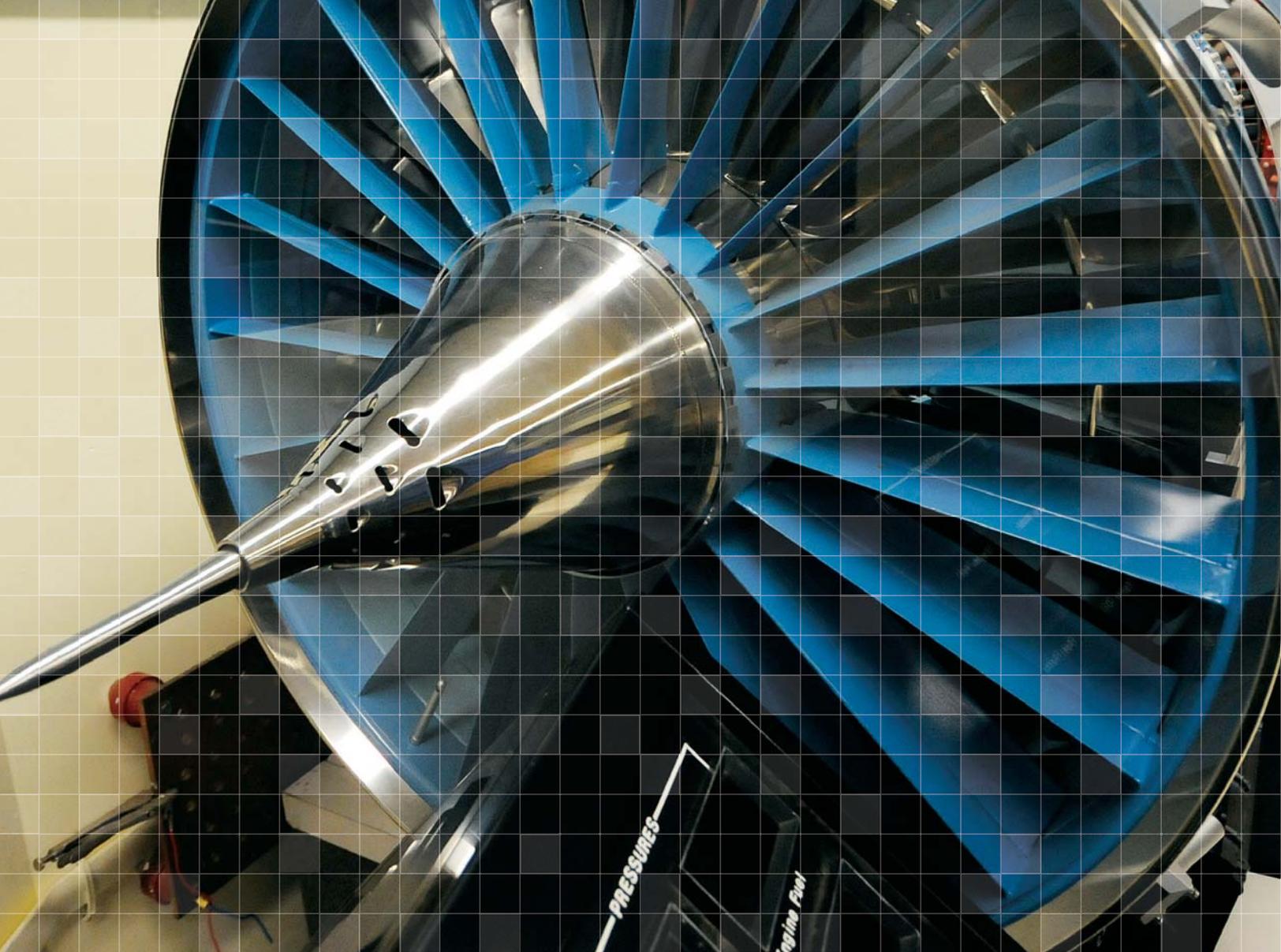
personnel in evaluating methods critical to increasing microalgae yields in commercial scale photobioreactor units. Without a doubt, both young men gained a wealth of knowledge that will be essential to our continuing work involving bioenergy in direct support of DoD, AF and USAFA alternative energy initiatives.

Meeting the intent of AFOSR's Bioenergy Program as well as the Academy's goal to establish an Alternative Energy program (NetZero 2015), LSRC has sought out partnerships to study the photosynthetic, growth and biomass properties of certain microalgae in hopes of optimizing biofuels production. Because of the chemical similarities between algae oils and petrochemical fuels, there is high interest in the use of microalgae in alternative fuels production.

These preliminary efforts in algae research are an important step towards establishing a pilot scale production facility at USAFA for larger scale biofuels production. This effort will subsequently benefit not only the Academy and larger DOD community, but will be a boon to local economic and industry growth.

"While classroom education is vital in preparing young men and women for leadership positions within the Air Force, the Academy also appreciates that conducting research is an exciting way to further refine their leadership development... learning how to manage their time, money and other resources is instrumental towards successful research," said Veverka of the many opportunities offered to cadets. "By dramatically expanding cadet and faculty research program opportunities beyond typical laboratory settings, we place our young leaders into "hands-on" research experiences, and thereby enrich the educational experiences of USAFA cadets and present yet another opportunity for faculty and cadets to work together to further USAF operational needs. Soon enough these young men and women grow into senior leaders and eventually, will make key Air Force decisions about executing critical research programs."





AERONAUTICS RESEARCH CENTER

Expanding Horizons

In the 15th century, when Leonardo da Vinci looked up to the sky, he envisioned flying machines beyond the scope of man's reach. Centuries later, that same curiosity and drive to create machines of flight takes hold of young cadets and propels them to solve the puzzles surrounding flight.

The Aeronautics Research Center (ARC) offers cadets a kaleidoscope of challenging aeronautics puzzles to investigate alongside Ph.D. faculty researchers from the Academy and throughout federal and private laboratories. This arrangement benefits cadets by providing world-class education

and research opportunities as well as Air Force, Department of Defense, NASA and commercial partnerships with high-quality research products.

"Over the years, ARC has developed and pursued the concept that education and research are best achieved when integrated. Extensive feedback from past cadets, research sponsors and the technical community suggest that USAFA achieves this better than any undergraduate Aeronautical Engineering institution in the country," said ARC director Dr. Tom McLaughlin.

The center will only accept projects that allow cadets hands-on research opportunities. The successful track record of research conducted by cadets (with the assistance of faculty mentors) continues to draw advanced research projects to the ARC ranging from NASA's Orion Crew Exploration Vehicle to hypersonic instrumentation development to alternative energy research. Project diversity and the challenges of each project offer these cadets opportunities to contribute to meaningful research and for USAFA faculty to remain active in their fields of research.

Wave power research has been conducted over the past several years under the direction of Dr. Stefan Siegel. Utilizing cycloidal propeller technologies, Dr. Siegel's team successfully demonstrated that a properly designed and controlled system can extract energy from deep ocean waves. In support of this research, the ARC completed construction of an in-house wave tank, and plans to begin experiments to validate the simulations in the near future.

Cadets also continued research on the KC-135 Winglets and Rakelets project and were able to demonstrate a 9% increase in overall fuel efficiency for the aircraft, using wingtip rakelets optimized over several semesters.

The ARC's relationship with NASA also continues to produce tangible results. Cadets, now 2nd Lieutenants, Darren Montes and Trenton West investigated parachute bay cover separation and parachute performance for NASA's Crew Exploration Vehicle (Orion). Cadets Montes

and West won the AIAA Regional Student Paper competition for their work and were finalists for the USAF Chief Scientist's Cadet Research Award. Both cadets briefed NASA on the results of the project on three separate occasions.

Research in the arena of remotely piloted vehicles is also a part of the center's efforts. Continuing projects include the Air Force Research Laboratory's Campus unmanned aerial vehicle (UAV) research and the Fighter Size Target project. Both projects have direct impacts on the Air Force's ability to train and respond to today's threats. The Campus project, a joint project with Lockheed Martin, has the potential to result in a new UAV test aircraft with advanced flow control technologies.

The Air Force Office of Scientific Research also provided substantial grants to the ARC during the 2009/2010 AY for continued efforts on Plasma Actuators and Flow Control for Flight Control. These projects are expected to generate \$800K to USAFA over the next three years. Additionally, the center's proposal to develop a Ludweig Tube, a hypersonic research facility, was recently accepted by the Defense University Research Instrumentation Program, and was granted \$930K for commissioning this state-of-the-art research tool.

"Our cadets leave with firsthand knowledge of the engineering process and the scientific method, and the Air Force and the nation benefit from this experience at the same time. As a result, the Air Force and Academy missions are well-supported by the Aeronautics Research Center's efforts," said McLaughlin.





MODELING AND SIMULATION RESEARCH CENTER

Growing Influence and Need for CFD Research

Advanced computational technologies are transforming cadet and faculty research at the Air Force Academy. Using these cutting-edge computational tools, cadets and faculty are conducting virtual experiments and modeling highly-complex aerodynamics. This provides the students with excellent learning opportunities while simultaneously addressing the challenges of flight in order to produce safer, more aerodynamically efficient and stable aircraft.

The Modeling and Simulation Research Center (MSRC) has created an environment allowing faculty and cadets to perform Modeling and

Simulation (M&S), using real-world High Performance Computing (HPC) tools. This research directly supports NASA, Department of Defense, National Science Foundation, Department of Homeland Security and Air Force research programs.

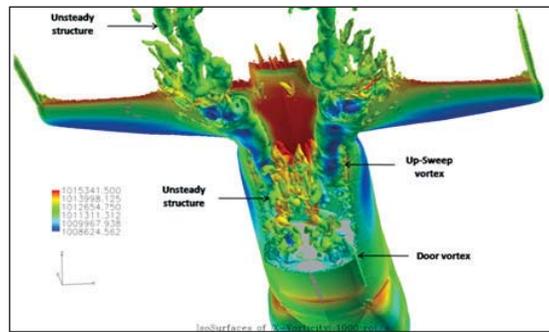
The MSRC is playing a critical role in the application of advanced computational fluid dynamics (CFD), the use of which is improving the safety and success rate of flight testing and dramatically reducing aircraft design, acquisition, and certification costs. One of the MSRC's ongoing projects is Computational Stability and Control (COMSAC) which is

developing methodologies for using virtual flight testing models in CFD to understand unpredicted dynamics occurring in flight tests. Cadets and faculty are currently simulating multiple F-16 flight maneuvers to understand the effects associated with control surface movement and aircraft response to aerodynamic loads.

Advanced CFD tools, such as advanced meshing techniques, hybrid turbulence modeling, and systems identification analysis are greatly improving the design and testing of modern-day aircraft and “could potentially save billions of dollars” according to Dr. Keith Bergeron, MSRC director. Dr. Bergeron said of previous aircraft programs that “despite their best efforts using the best available predictive capabilities, nearly every major fighter program since 1960 has had costly nonlinear aerodynamic or fluid-structure interaction issues that were not discovered until flight testing”. He also said that “Using advanced computational fluid dynamics (CFD) methods; simulations are now capable of capturing the unsteady nonlinear aerodynamic behavior that leads to the various static and dynamic instabilities associated with highly-maneuverable aircraft.”

The center aspires to providing cadets with extensive, learning-focused opportunities both in and out of the lab. Over 90 cadets participated in computational aerodynamics and physics courses during the 2009/2010 academic year and the center sponsored five cadets and two faculty researchers to conduct cadet summer research programs in Hawaii and Florida in the summer of 2010.

Cadets in the Aeronautics Department are using computational methods to accurately determine static and dynamic stability and control characteristics of fighter aircraft with various weapons configurations. These methods are being successfully applied to the F-16C and the F-22. The simulations and the proposed modeling process will result in improved stability and control analysis as compared to the traditional wind-tunnel generated database approach. The new approach will also provide flexibility when encountering new weapons configurations needed by the warfighter.



The center has also continued to conduct research on airdrops and fluid-structure interactions. Cadets are using a combination of experiments and CFD to identify key aspects of airflow around aircraft that influences the airdrop of cargo and mission personnel. Another long-term project is the center’s Aero-Servo-Optics research to develop an accurate understanding and predictive capability of the effects of boundary and shear layers on optical performance of airborne laser systems.

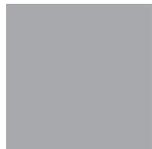
A collaborative effort with the Academy’s Center of Innovation known as Mission Fabric and Flexible Distributed Control/Coordination is also underway. The goal of this project, funded in part by the Office of the Secretary of Defense (OSD) and the Department of Homeland Security (DHS), is to build a network designed as a system of systems to place intelligence at the node-level and enhance distributed collaboration and ad hoc group action to create a single complex adaptive system. The success of last year’s experiment has led to an additional \$3M in funding from OSD and DHS.

The MSRC provides Air Force Academy cadets with learning-focused, sponsored research opportunities using state-of-the-art computational tools in support of real-world problems. As stated by Dr. Bergeron, “Today’s high performance computational technologies open a new approach to the application of the principles of science toward satisfying Air Force needs. These M&S capabilities enable our cadets to perform research that would only have been found in graduate-level programs five years ago”.





FUNDING FOR RESEARCH AT USAF ACADEMY



The value of the research program at the Academy is worth more than just the monies donated. The funding impacts cadets' ability to conduct research that supports their livelihood as an officer. Financial support is at an all time high, with funding arriving through two primary vehicles—the first vehicle being Memoranda of Understanding (MOU)/Memoranda of Agreement (MOA) with Air Force, Department of Defense, and other federal agencies, and the second vehicle is through Cooperative Research and Development Agreements (CRADA) with non-federal entities. These provide rich research opportunities allowing cadets to get involved in hands-on experience that involves real world and Air-Force relevant issues.

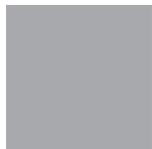


The value of research programs has grown to a remarkable high point of \$59 million for



the 2010 Academic Year (AY). This can be broken into three main categories: External In-Kind, External Funding, and Internal Support. External In-Kind support includes the value of visiting researchers and in-kind supercomputer time contributed by the Department of Defense High Performance Computing Modernization Office, which totaled \$7.5 million. External funding is the direct monetary funding that research centers receive from outside partners. The Internal support value is determined by an econometric evaluation of USAFA-provided laboratory facilities, depreciation of capital equipment, and USAFA personnel time, and totaled \$11.1 million.

Figure 1 shows the increase in growth in USAFA research since 2001. As the last decade indicates, the area of most growth continues to be in External Funding. Figure



2 indicates the sources of research funding. Outside partners contribute to the significant growth rate of external funding. Following the trend of years past, external funding growth is largely due to the agreement between USAFA's Center for Aircraft Structural Life Extension

(CASTLE) and Oklahoma City Air Logistics Center for the KC-135 Structural Teardown. USAFA continues to receive core funding from the Air Force Office of Scientific Research, the basic research manager of the Air Force Research Laboratory.



Econometric Value

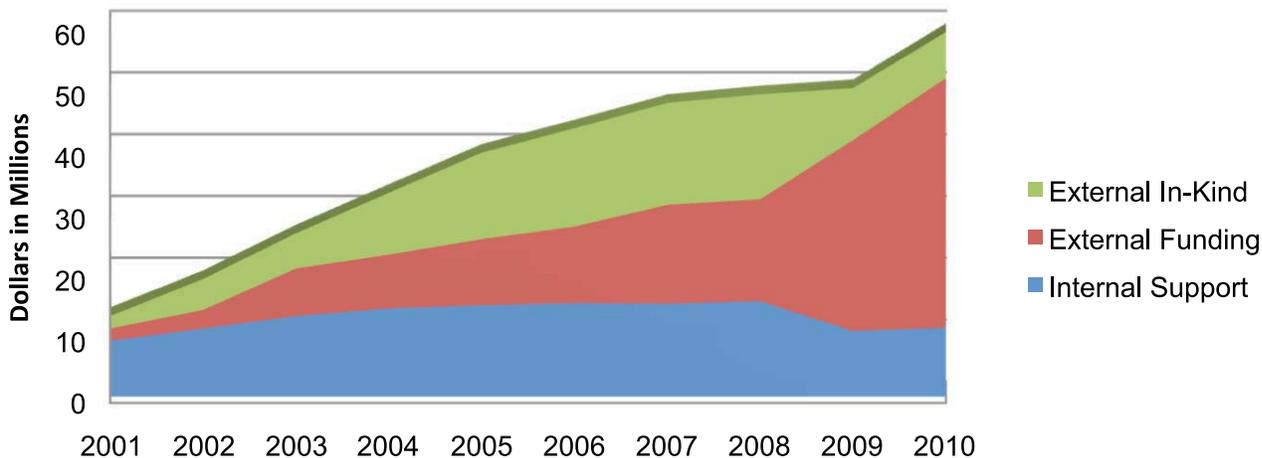


Figure 1

Research Funding Sources

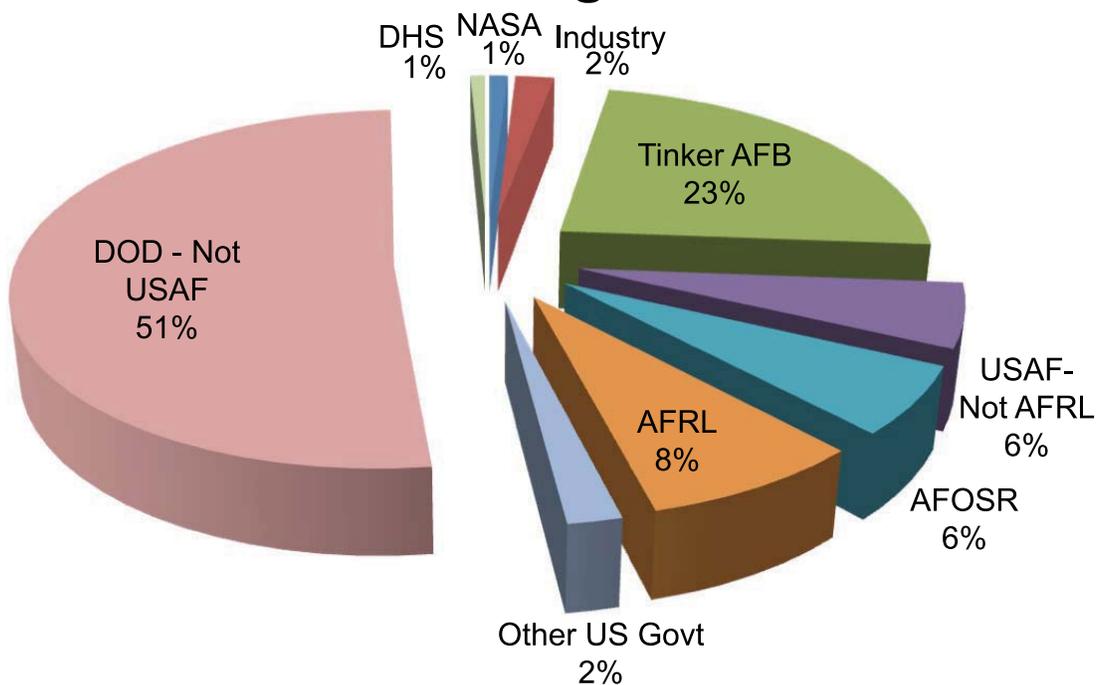


Figure 2

2009/2010 ACADEMIC YEAR PUBLICATIONS HIGHLIGHTS

During the 2009/2010 academic year, USAFA researchers published more than 550 publications in peer reviewed journals, conference proceedings and presentations, and in other professional publications.

We are **spotlighting just a few** of our research centers and institutes **2009/2010 academic year publications** in this year's research report to further show the dedication of our faculty not only to educating our nation's and Air Force's next generation of leaders but also to their commitment to conducting respected, meaningful research in their chosen fields.

Aeronautics Research Center

Seidel, J.; Siegel, S.; Fagley, C.; Cohen, K. & McLaughlin, T. "Feedback control of a circular cylinder wake" *J. Aerospace Eng.*, 2009, *Special issue*, 379-392. *This paper received the Aerospace Industries Division of the Institute of Mechanical Engineers' Kenneth Harris James Prize.*

Aradag, S.; Siegel, S.; Seidel, J.; Cohen, K. & McLaughlin, T. "Filtered POD-based low-dimensional modeling of the 3D turbulent flow behind a circular cylinder" *Int. J. Num. Methods Fluids*, 2010

Darren R. Montes, Trenton J. West and Thomas R. Yechout (Research Advisor) "Experimental Aerodynamic Investigation of NASA Orion Forward Bay Modifications", presented at AIAA Region V Student Paper Competition, Wichita, KS, 2010

Space Systems Research Center

Lawrence, Timothy J., William W. Saylor, Kenneth E. Siegenthaler, and Thomas G. Ward, Jr., "Space, Science and Technology," *Space and Defense Policy*, invited chapter in a book edited by Damon Coletta and Frances T. Pilch, Eisenhower Center for Space and Defense Studies, Space Power and Politics Series, Routledge, Taylor and Francis Group, New York, 2009.

Siegenthaler, Kenneth E., and Timothy J. Lawrence, "Null Findings of Yamishita Electrogravitational Patent,"

Frontiers of Propulsion Science, invited chapter in a book edited by Marc G. Millis and Eric W. Davis, Volume 227 in the AIAA Progress in Astronautics and Aeronautics Series, American Institute of Aeronautics and Astronautics, Inc., Reston, Virginia, 2009.

Lawrence, Timothy J., et al., "The United States Air Force Academy FalconSAT Small Satellite Program," *Small Satellite Design*, invited chapter in a book edited by Helvajian, Aerospace Press, 2009.

Center for Aircraft Structural Life Extension

M. Hammond, Börje Andersson, S. Fawaz, J. Greer and R. Rainsberger, "Detailed Three-Dimensional Modeling of the C-130 Center Wing Box for Damage Tolerance Analyses", *2010 Aircraft Airworthiness and Sustainment Conference*, Austin, TX, 10-13 May, 2010.

S. Galyon, F. Fawaz, Y. Lee, D. Sweeney and J. Warner, "Environmental Fatigue Crack Propagation in AA7075-T651" *2010 Aircraft Airworthiness and Sustainment Conference*, Austin, TX, 10-13 May, 2010.

G.A. Shoales, "Procedures for Aircraft Structural Teardown: Development of a Best Practices Handbook," *25th International Conference on Aeronautical Fatigue Symposium*, Rotterdam, Netherlands, 27-29 May 2009.

The Academy Center for Unmanned Aircraft Systems Research

Pedro Lima and Daniel Pack, "Maximizing Search Coverage Using Future Path Projection for Cooperative Multiple UAVs with Limited Communication Ranges," invited chapter in *Optimization and Cooperative Control Strategies*, Lecture Notes in Control and Information Sciences, Springer Berlin/Heidelberg, vol. 381-1, 2009.

Steve Barrett and Daniel Pack, "Textbooks 101: A Primer on Writing Your First Book," *IEEE Computer*

Society Computing in Science and Engineering Magazine, pp. 2-6, March/April, 2010.

Daniel Pack, Pedro Delima, Gregory Toussaint, and George York, "Cooperative Control of UAVs for Localizing Intermittently Emitting Mobile Targets," *IEEE Transactions on System, Man, and Cybernetics*, vol. 39, No. 4, pp 959-970, August, 2009.

The Human Performance Lab

Brothers MD, Doan BK, Wile AL, Zupan MF, Wilber RL, and Byrnes WC. "Hematological and physiological adaptations following 48 weeks of moderate altitude residence." *High Alt Med Biol*, accepted with revision, in press Jul 2010?

Wilson C and Brothers MD. "Iron deficiency in women and its' potential impact on military effectiveness." *Nursing Clinics of North America*, 45 (2): in press Jun 2010.

Ryan B, Brothers MD, Nelson JL, Doan BK, Zupan MF, Prommer N, and Byrnes WC. "Factors influencing haemoglobin mass at moderate altitude in acclimatized USAFA cadets." *Eur J Appl Physiol*, submitted for publication.

The Academy Center for Cyberspace Research

Schweitzer, D., Boleng, J., Hughes, C., and Murphy, L. "Visualizing Keyboard Pattern Passwords," *Proceedings of the International Workshop on Visualization for Computer Security, VizSec'09*, October 2009.

Schweitzer, D., Boleng, J. "A Simple Machine Simulator for Teaching Stack Frames," *Proceedings of the 41st ACM Technical Symposium on Computer Science Education, SIGSCE 2010*, March 2010.

Baird, L. "Cryptography for Cyber Security and Defense: Information Encryption and Cyphering," *IGI Global book chapter*.

Space Physics and Atmospheric Research Center

H. S. Feldmesser, M. A. G. Darrin, R. Osiander, L. J. Paxton, A. Q. Rogers, J. A. Marks, M. G. McHarg, R. L. Balthazor, L. H. Krause, and J. G. FitzGerald. "

CANARY: ion spectroscopy for ionospheric sensing," *Proc. SPIE 7691, 76910K* (2010)

N. Y. Liu, V. P. Pasko, K. Adams, H. C. Stenbaek-Nielsen, and M. G. McHarg. "Comparison of acceleration, expansion, and brightness of sprite streamers obtained from modeling and high-speed video observations", *Journal of Geophysical Research*, Vol 114, 2009.

H. C. Stenbaek-Nielsen, R. Haaland, M. G. McHarg, B. A. Hensley, and T. Kanmae. "Sprite initiation altitude measured by triangulation," *JOURNAL OF GEOPHYSICAL RESEARCH*, VOL. 115, A00E12, doi:10.1029/2009JA014543, 2010

Modeling & Simulation Research Center

S. Goertz, A. Jirasek, S.A. Morton, D.R. McDaniel, R.M. Cummings, J.E. Lamar, and K.S. Abdol-Hamid, "Standard Unstructured Grid Solutions for Cranked Arrow Wing Aerodynamics Project International F-16XL," *Journal of Aircraft*, Vol. 46, No. 2, 2009, pp. 377-384.

L. Schiavetta, O.J. Boelens, S. Crippa, R.M. Cummings, W. Fritz, K.J. Badcock, "Shock Effects on Delta Wing Vortex Breakdown," *Journal of Aircraft*, Vol. 46, No. 3, 2009, pp. 903-914.

D.R. McDaniel, R.M. Cummings, K. Bergeron, S.A. Morton, and J.P. Dean, "Comparisons of CFD Solutions of Static and Maneuvering Fighter Aircraft with Flight Test Data," *Proc IMechE Part G, Journal of Aerospace Engineering*, Vol. 223, No. 4, 2009, pp. 323-340.

Laser and Optics Research Center

B.V. Zhdanov, M.K. Shaffer, and R.J. Knize, "Cs laser with unstable cavity transversely pumped by multiple diode lasers," *Opt. Express* 17, 14767-14770 (2009)

Benjamin Ward and Justin Spring, "Finite element analysis of Brillouin gain in SBS-suppressing optical fibers with non-uniform acoustic velocity profiles," *Opt. Express* 17, 15685-15699 (2009)

Justin Spring and Benjamin Ward, "Brillouin gain suppression in photonic crystal fibers with random acoustically microstructured cores," *Opt. Lett.* 35, 31-33 (2010)



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