AFRL

THE AIR FORCE RESEARCH LABORATORY

Discovering and Delivering For Tomorrow's Force

ANNUAL REPORT 2021

AFRL

CONTENTS

afresearchlab.com

PREFACE

Dear Reader,

I want to share AFRL's journey with you. Over the past two years, AFRL took action to implement new and better ways to accomplish our science and technology (S&T) mission. We took the *Department of the Air Force S&T 2030 Strategy* to heart and inculcated its tenets into our day-to-day research, our partnerships, our human capital strategy, and more.

In this report, you will see how we ***Accelerate S&T*** to answer today's challenges, such as how AFRL assisted in the national COVID-19 response and how we developed solutions to counter the threat of small drones. You will learn about our innovation ecosystem and our technology accelerators—AFWERX, SpaceWERX, and the Center for Rapid Innovation. You will see a stronger S&T portfolio that consolidates efforts to defeat our adversaries and a new Transformational Capability Office that accelerates revolutionary concepts to support Airmen and Guardians.

You will also review AFRL's commitment to ***One Lab supporting Two Services***—an Air Force and a Space Force. We established a new Deputy Technology Executive Officer for Space S&T and harnessed the power of relevant scientific areas, such as artificial intelligence, autonomy, biotechnology, cyber, quantum, microelectronics, and hypersonics, to advance operations outside the Earth's atmosphere.

Throughout these pages, you will meet our workforce, who are the source of our technological advantage. These professional risk-takers use science to develop innovative operational solutions and ***Build the Best Teams*** through a continuous talent pipeline. Our 2021 AFRL Fellows exemplify these gifted unicorns through their extraordinary career accomplishments. Lastly, you will see how we further expanded our network to access novel sources of ideas from academia, small businesses and industry, as well as international partners and allies.

As AFRL continues its journey, our commitment to the warfighter is stronger than ever. We remain focused on the future and ready to take on opportunities that lead to discoveries and solutions for future operational dominance.

– Major General Heather L. Pringle
Commander, Air Force Research Laboratory

U.S. AIR FORCE

USSF

AFRL

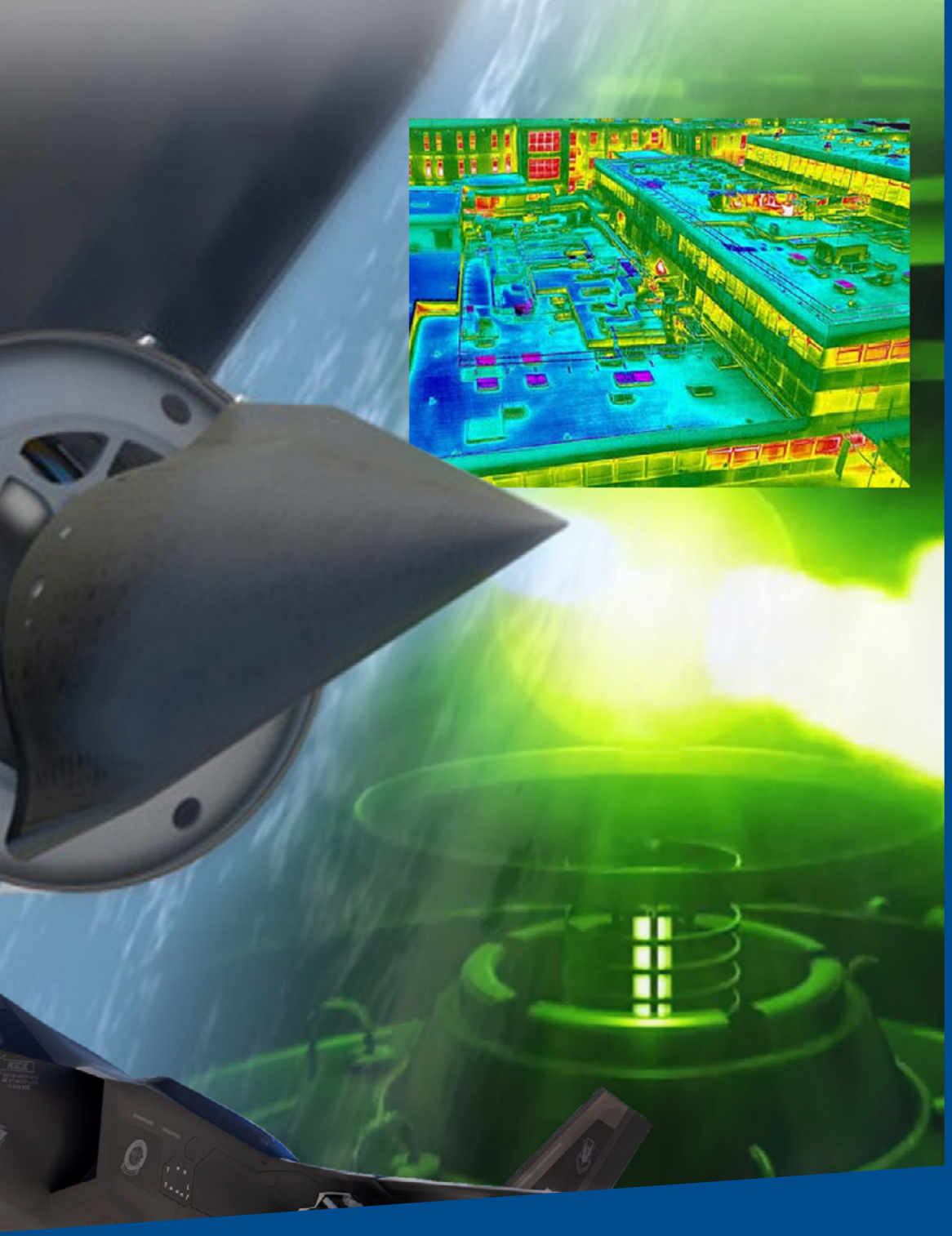
EXECUTIVE SUMMARY

The Air Force Research Lab (AFRL) develops tomorrow's technology for the Department of the Air Force. Comprised of 15 organizations located throughout the United States, with approximately 11,750 dedicated civilian employees, military personnel, and contractors, AFRL supports the US Air Force and US Space Force missions in air, space, and cyberspace.

In the pages of this report, you will see how AFRL accomplishments supported the Department of the Air Force's mission and modernization efforts throughout 2021. Leveraging the Department's S&T investments to provide demonstrable research outputs, AFRL researchers have delivered capabilities for today's warfighters, while supporting the Air Force and Space Force transformation to meet tomorrow's challenges. To meet the challenges of managing a large and distributed research organization, AFRL has adopted new initiatives, like the Transformational Capabilities Office's Vanguard programs; incorporated new organizations into its mantle, such as AFWERX; and begun implementing a new Human Capital strategy to ensure the Lab continues to possess the appropriate resources to conduct impactful research for the Department of the future.

In Fiscal Year 2021, AFRL executed approximately $6.9 billion in Research, Development, Test, and Evaluation funds. This funding supports research conducted by employees and contractors located at AFRL laboratory sites, as well as contracted research conducted by academic and industry experts in the United States and throughout the world. These efforts span Departmental missions and priorities, including providing US operators **Space Superiority** and **Information Dominance**, enabling the force's **Global Power** and **Global Reach**, and leading the Department's **Discovery** of new scientific knowledge. This report provides a sample of AFRL's impact to each of these areas.

Moving forward, AFRL will create tomorrow's technology for the Department of the Air Force, delivering solutions to our warfighter's urgent needs, providing innovative new capabilities for the Air Force and Space Force, and ensuring national security through US dominance in air and space.



Mission

Leading the discovery, development, and integration of affordable warfighting technologies for our air, space, and cyberspace forces.

Vision

We defend America by unleashing the power of innovative air and space technology.

AFRL

THE AIR FORCE RESEARCH LABORATORY

LEAD | DISCOVER | DEVELOP | DELIVER

LEAD

We lead the Air Force and Space Force in science and technology.

DISCOVER

We are at the forefront of innovation. We explore, research, and push the boundaries of technology.

DEVELOP

We bridge the gap between research and application. We provide the Air Force and the Space Force with the technology it needs to defend America.

DELIVER

We provide superior technology to warfighters in a continuous manner. We identify future needs and advance technologies to support these capabilities.

Tracing its roots back over 100 years, AFRL is the primary scientific research and development center for the Department of the Air Force (DAF). Headquartered at Wright-Patterson Air Force Base in Dayton, Ohio, the Lab was formed in 1997 via the consolidation of the four Air Force laboratories along with the Air Force Office of Scientific Research. Today's AFRL encompasses sites in ten states and maintains offices in four foreign countries, executing a budget of approximately $6.9 billion in funds during fiscal year 2021. The Lab's efforts, spread across 15 organizations, continue to evolve with the Department of the Air Force ensuring it fully delivers on its mandate to serve as One Lab for Two Services.

Enhancing Mission Capabilities

ORGANIZATIONAL CHART

AFRL Commander
DAF TEO
Maj. Gen. Heather Pringle

Executive Director
Mr. Timothy Sakulich

Chief Technology Officer
Dr. Timothy Bunning

Vice Commander
Col. Paul Henderson

Deputy TEO for Space S&T
Dr. Andrew Williams

Mobilization Asst. to the Commander
Col. Michael McGinley

Command Chief
CMSgt. James Fitch

Aerospace Systems
Dr. Michael Gregg

Air Force Office of Scientific Research
Dr. Shery Welsh

AFWERX
Col. Nathan Diller

Directed Energy
Dr. Kelly Hammett

Information
Col. Fred Garcia II

Materials and Manufacturing
Dr. Chuck Ward, Acting

Munitions
Col. Woodrow Meeks

Strategic Development Planning and Experimentation
Mr. Christopher Ristich

Sensors
Ms. Amanda Gentry

Space Vehicles
Col. Eric Felt

Systems Technology Office
Mr. William Cuzick

Transformational Capabilities Office
Mr. Christopher Ristich

711th Human Performance Wing
Brig. Gen. (Dr.) John Andrus

Airman Systems
Mr. J. Mark Coleman

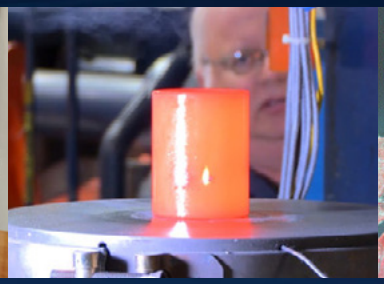
USAF School of Aerospace Medicine
Col. (Dr.) Tory Woodard

SCIENCE AND TECHNOLOGY INNOVATION DRIVERS

Throughout each of the Laboratory's divisions, AFRL personnel work on technologies across all aspects of the Department of the Air Force's mission areas and to meet the needs of Airmen and Guardians in the field.

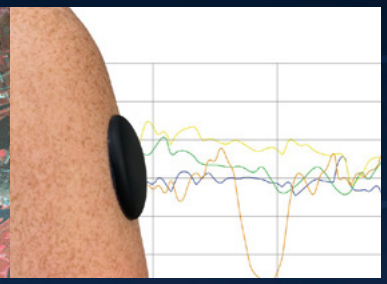
AEROSPACE SYSTEMS

AIRMAN SYSTEMS



MATERIALS & MANUFACTURING

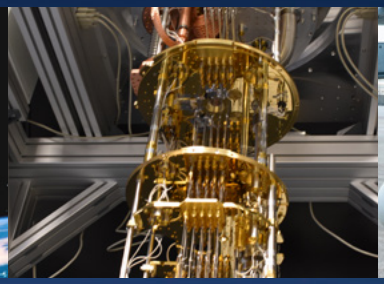
SENSORS



711TH HUMAN PERFORMANCE WING

DIRECTED ENERGY

SPACE VEHICLES



INFORMATION

MUNITIONS

AFWERX

STRATEGIC DEVELOPMENT PLANNING & EXPERIMENTATION

TRANSFORMATIONAL CAPABILITIES OFFICE

AIR FORCE OFFICE OF SCIENTIFIC RESEARCH

USAF SCHOOL OF AEROSPACE MEDICINE

SYSTEMS TECHNOLOGY OFFICE

CAREER FIELDS AT THE LAB

Professional

- Accounting
- Budget Analyst
- Contracting
- Electronics Technician
- Engineering Technician
- Facility Management
- Financial Management
- Foreign Affair Specialist
- Health System Specialist
- Instructional Systems
- Intelligence
- IT Management Logistics Management
- Librarian
- Manpower and Personnel
- Physical Science Technician
- Physician
- Police
- Program Management
- Public Affairs
- Safety/Occupational Health
- Secretary
- Security
- Other

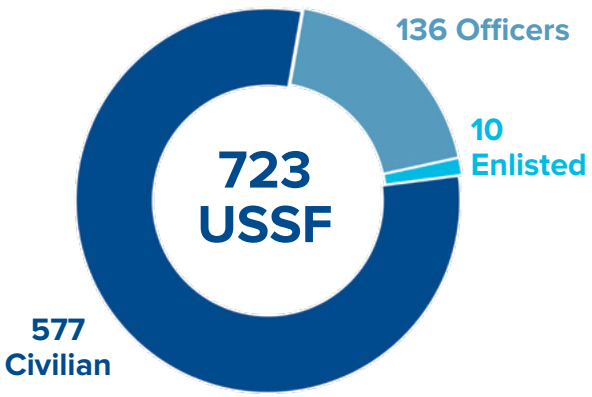
Science

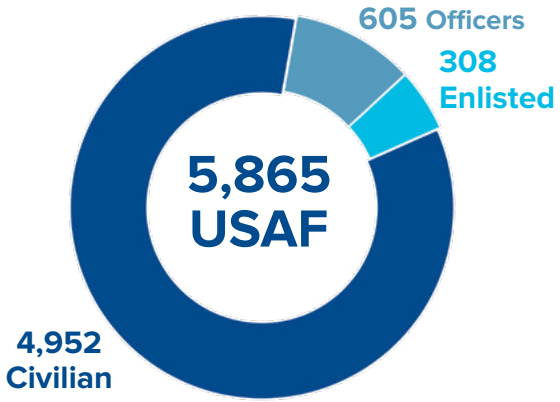
- Chemistry
- Clinical Laboratory
- Computer Science
- General Biological Sciences
- General Medical and Healthcare
- General Physical Sciences
- Industrial Hygiene
- Mathematics
- Operations Research
- Physics
- Physiology
- Psychology
- Other Science

Engineering

- Aerospace
- Bioengineering and Biomedical
- Chemical
- Computer
- Electrical
- Electronics
- Engineering and Architecture Student Trainee
- General
- Materials
- Mechanical
- Safety
- Other Engineering

6,588 EMPLOYEES

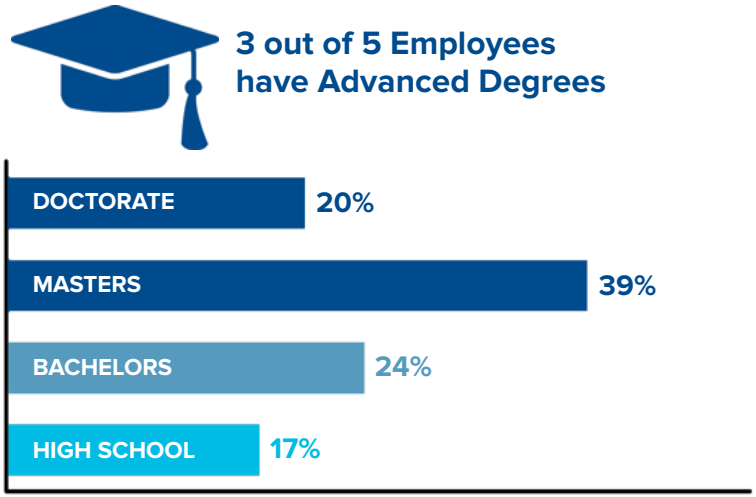




PLUS 5,180 ONSITE CONTRACTORS

AFRL IS POWERED BY 11,768 DEDICATED PEOPLE

3 out of 5 Employees are Scientists or Engineers



AFRL's systems approach to human capital creates a more cohesive workforce experience and scales to support high performing teams and organizational performance.

READ MORE AT:
afresearchlab.com

AFRL IS FOSTERING ITS FUTURE FORCE

In 2021, AFRL began employing a new human capital lifecycle systems model to integrate educational STEM Outreach; the Enterprise Internship Pipeline; Human Resources and Personnel Management; continuous learning and organizational health and development; and Diversity, Equity, and Inclusion. With continual analytics, AFRL is generating strategic foresight to capitalize on and empower its most important asset—the driven and dedicated personnel of the Lab.

This approach uses data to inform AFRL on the priorities that must be addressed to support our people now and into the future through descriptive and predictive data analytics. It creates a more cohesive workforce experience and scales to support high performing teams and organizational performance. This approach embraces and institutionalizes innovation in human capital practices and policies. By assessing trends and influences on the talent market and the future of work, AFRL can prepare today for the future by continuously scanning for, applying, and pioneering leading human capital practices for the maximum benefit of all our people. In one such exciting initiative, the Lab will now help employees pay back up to $125K in college expenses.

GOAL 1

Strategically access, attract, acquire, and retain top talent.

GOAL 2

Develop our current and future workforce to thrive amidst change.

GOAL 3

Enhance diversity, equity, and inclusion.

GOAL 4

Achieve organizational flexibility.

GOAL 5

Transform the human capital function into a strategic advantage.

THE BEST AND BRIGHTEST

Each year AFRL selects an elite cadre of AFRL Fellows and Science and Engineering Early Career Award recipients from among the amazing pool of AFRL scientists and engineers in recognition of their outstanding accomplishments. The 2021 group includes ten Fellows and seven Science and Engineering Early Career Award winners. Maj. Gen. Pringle commended the winners' achievements, emphasizing their "ingenuity and insight in their respective fields" as well as their commitment to the nation's warfighters. Both are essential to the Department's success in today's environment of strategic competition.

The AFRL Fellows program recognizes outstanding scientists and engineers in three categories: research achievements, technology development and transition achievements, and program and organizational leadership. The induction of this year's Fellows—who delivered significant contributions to the DAF in a wide variety of technical areas, including weapon seeker technologies, automatic target acquisition and recognition, alternative precision navigation, and hypersonic weapons—brings the total number of AFRL Fellows to 233 since the program's introduction in 1987. Truly rarified company.

The AFRL Science and Engineering Early Career Award recognizes junior scientists and engineers for significant research or engineering achievements during the onset of their career. The award is specifically for scientists and engineers who are in the first seven years of their careers, representing the great promise of tomorrow's AFRL.

READ MORE AT:
afresearchlab.com

AFRL FELLOWS


Mr. Anthony Cain


Dr. Michael Cinibulk


Dr. Gary Cook


Dr. Brad Hoff


Dr. T.J. Klausutis


Dr. Joseph Lyons


Dr. Evgeny Mishin


Dr. Todd Pedersen


Ms. Carolyn Sheaff


Ms. Lori Westerkamp

EARLY CAREER AWARD RECIPIENTS


Dr. J. Daniel Berrigan


Dr. Philip Buskohl


Dr. Christopher Petersen


Dr. Gretchen Phelps


Dr. Casey Pirnstill


Dr. Michael Steinbock


Dr. Alan Wall

Although AFRL can only recognize a small number of its own as Fellows and Early Career Award winners, researchers throughout the Lab represent the very best and brightest in their respective fields. Sought out and acknowledged by their technical communities for their intellectual merit, 96 AFRL researchers are currently recognized as Fellows by domestic and international learned organizations.

AFRL researchers bring the same dedication to the scientific community as they do to the warfighter. Volunteering their time to chair professional societies, serve on advisory committees, and contribute to technical review committees, AFRL scientists and engineers represent the uppermost echelon of the scientific community. They deliver tirelessly not only for the warfighter, but for science and society as a whole. AFRL is proud to call them all team members.

107 **Serve on Leadership/ Advisory Committees**

103 **Serve in Leadership Roles in Professional Societies**

96 **Recognized with Domestic or International Fellowships**

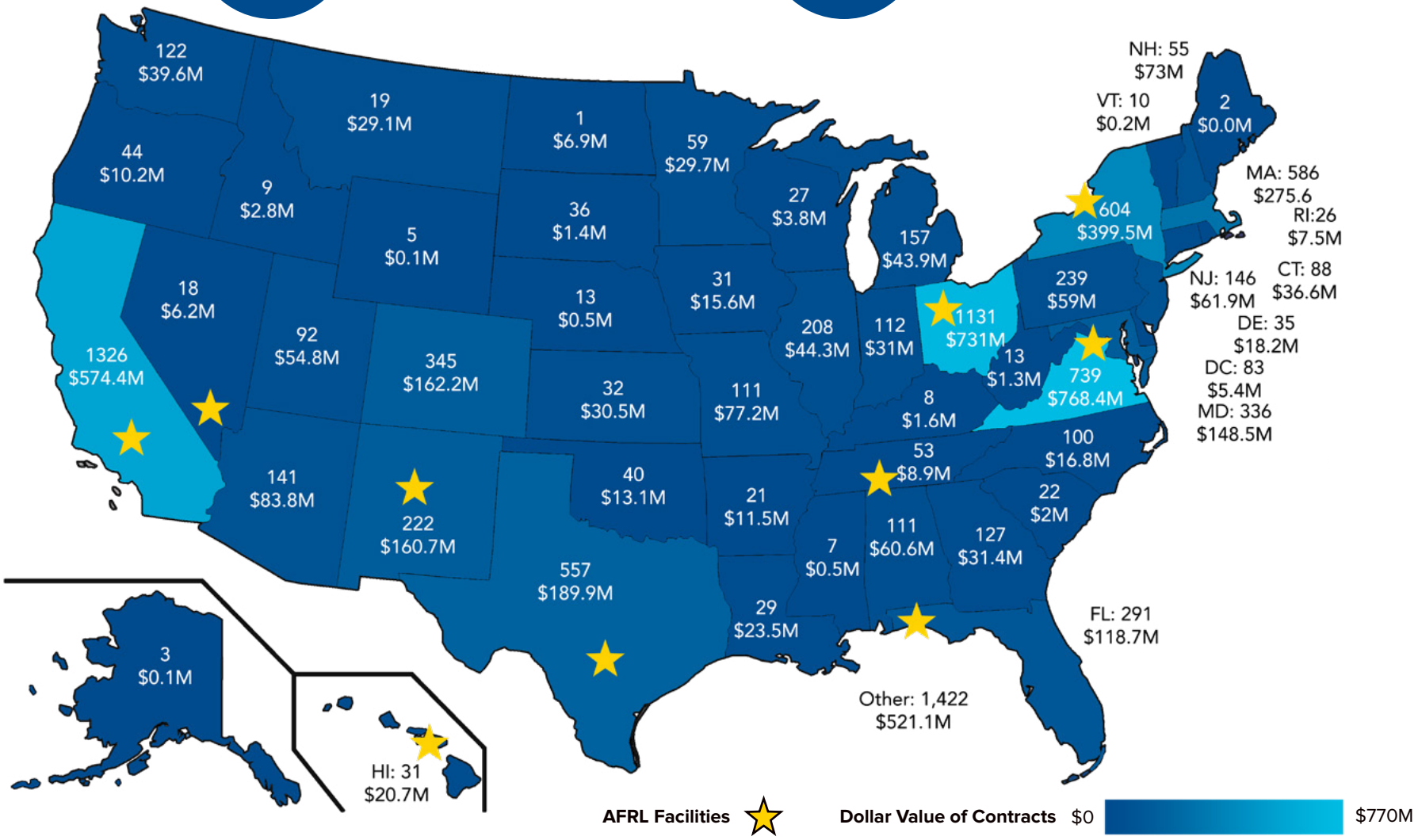
31 **Chair Professional Society Committees**

206 **Chair External Technical Committees**

AFRL ACROSS THE COUNTRY...

10,056 Contracts with industry, universities, and research institutions

2,284 Agreements to share technologies, data, and discoveries



The map indicates number and total dollar value of active contracts in each state.

....AND AROUND THE WORLD

52 Countries

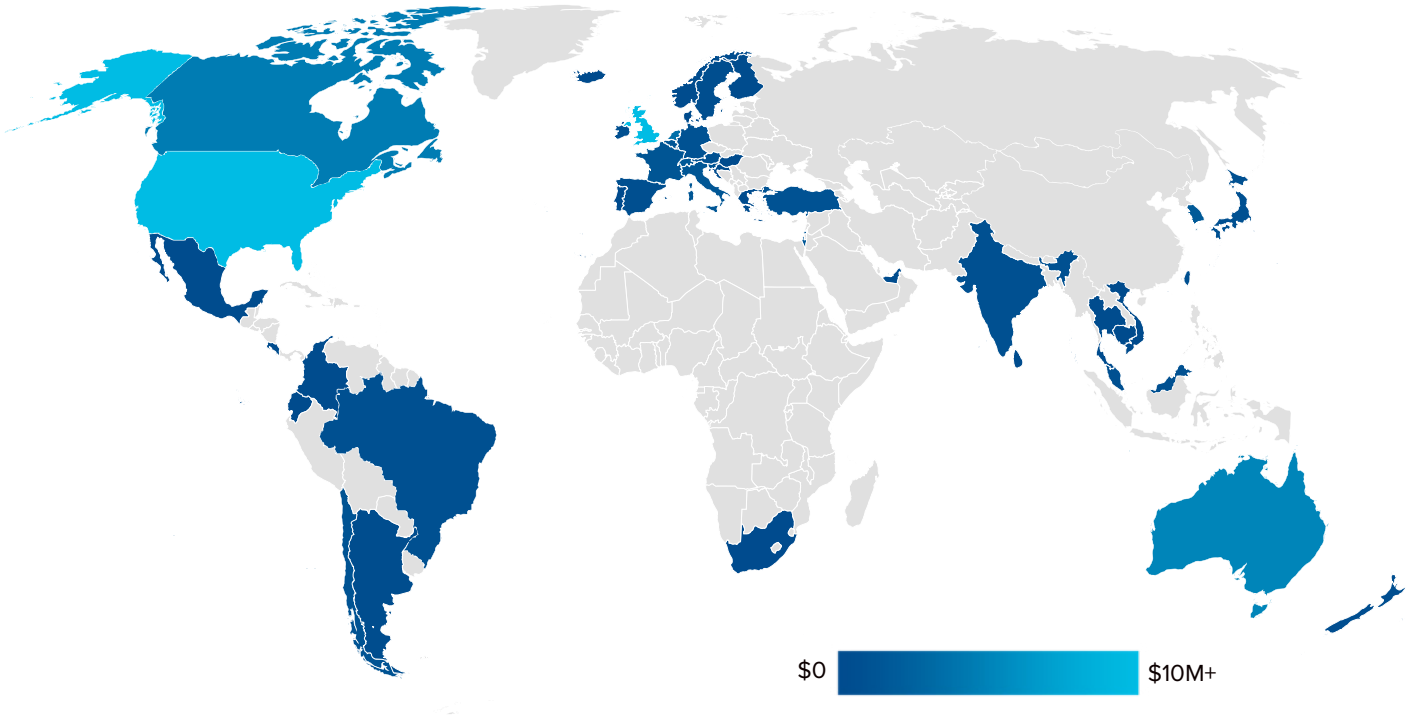
811 Grants & Agreements

363 International Research Agreements

Largest International Partners

Grants/Agreements

United Kingdom	106
Australia	83
South Korea	37
Italy	27
Canada	26
Israel	18
Malaysia	17
Germany	17
France	16
Chile	16
Brazil	16



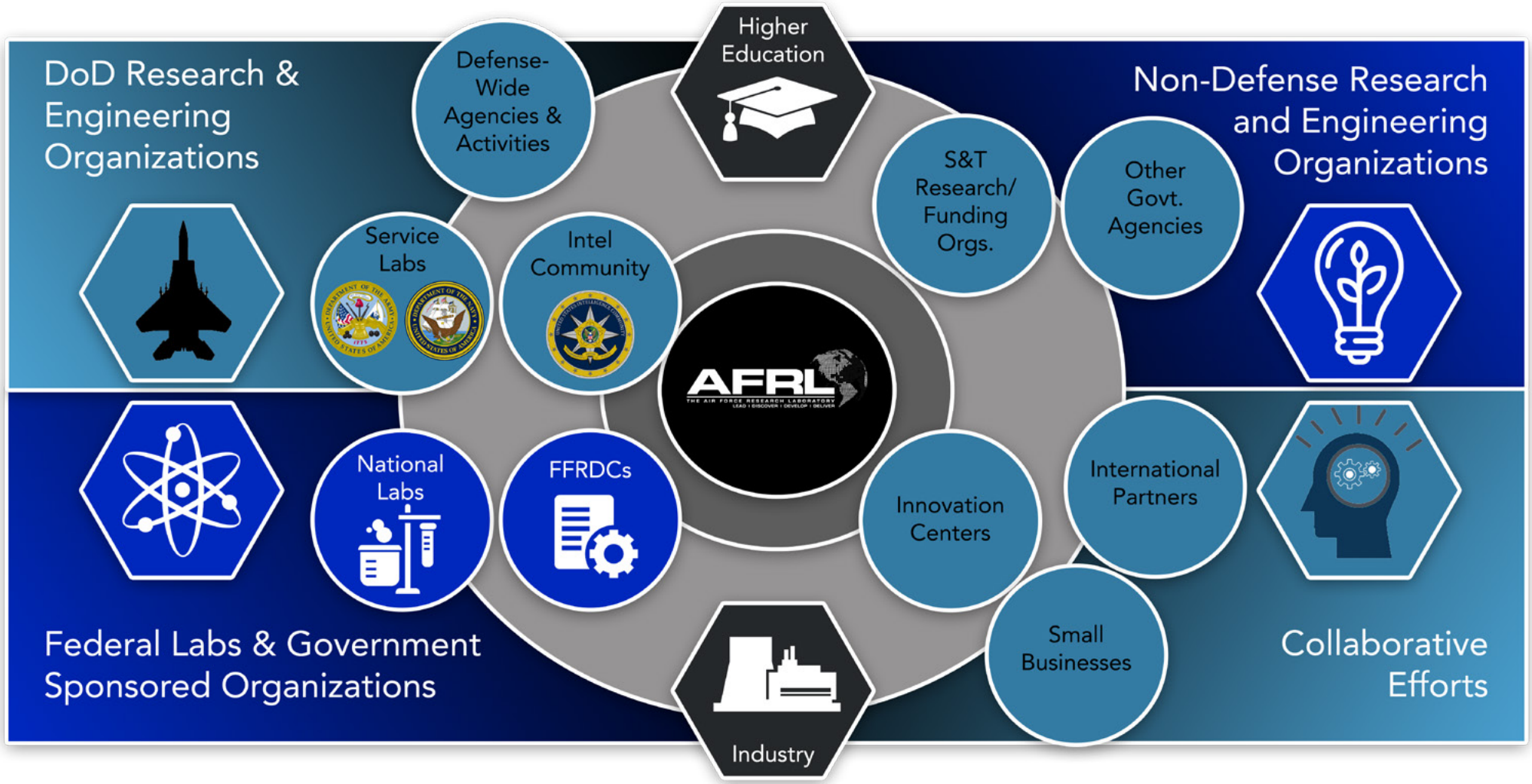
WITH OFFICES IN...

South America

Asia

Europe

Oceania



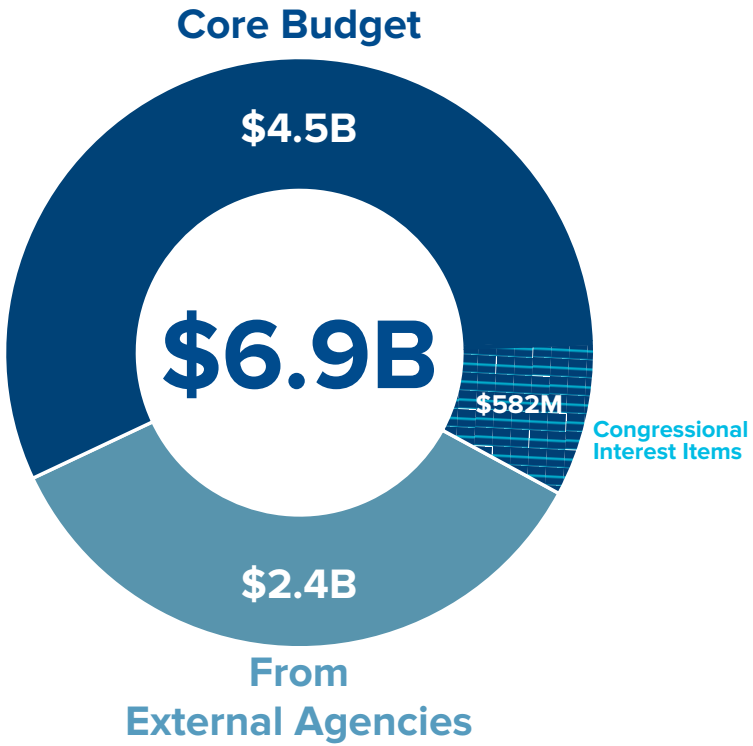
AFRL COLLABORATES

with an extensive network of research and development organizations, enabling the Department of the Air Force to uncover, understand, and deliver the best capabilities to the warfighter.

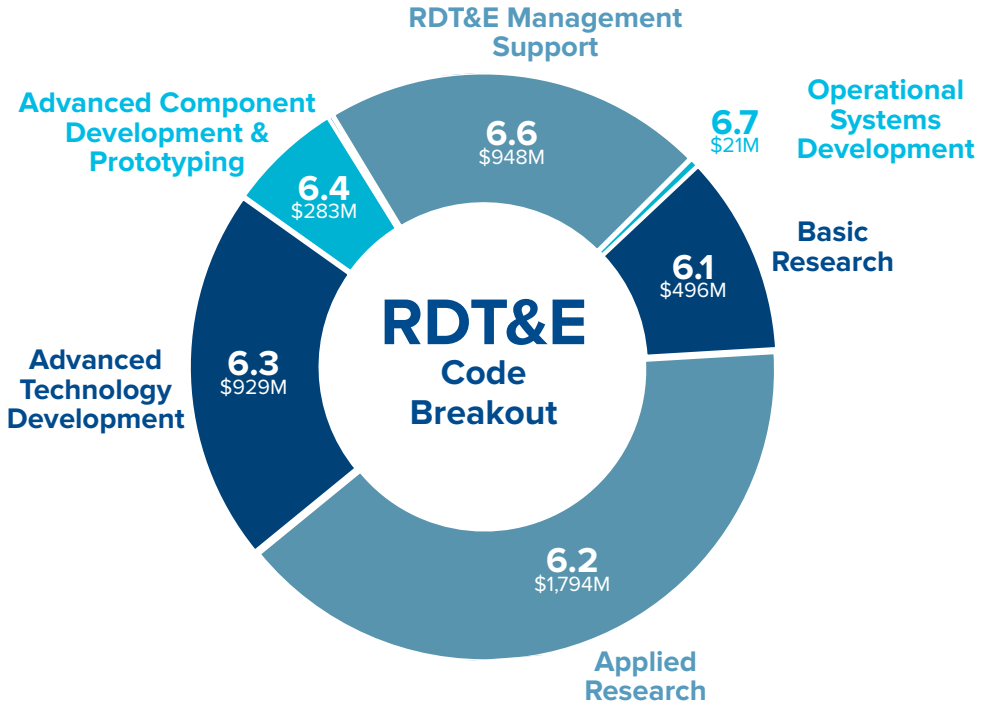
AFRL INVESTS across the Research Development Test & Evaluation spectrum

With an internal budget of $4.5B in Congressionally authorized Research Development Test & Evaluation (RDT&E) funds and executing an additional $2.4B in funds from other S&T agencies, the Lab contributes to efforts throughout the national security community. Such collaboration is driven by the expertise and commitment of AFRL personnel as they work to deliver new technologies and novel capabilities to operators.

TOTAL BUDGET IN FY21



CORE BUDGET BREAKOUT



AFRL DELIVERS

In order to impact Department of the Air Force systems, AFRL researchers mature and evolve technology from ideas, to the bench, and to fielded systems–across all domains of research. Knowledge-based scientific discoveries fuel the research and development of new hardware capabilities and software tools that can be incorporated into the next generation of systems to support the warfighter, putting the latest technologies into their hands. To grow and support the American scientific community, AFRL's scientists and engineers conduct research published in scientific journals, books and book chapters, technical reports, present their findings to peers at scholarly conferences, and file patents.

Each year, AFRL research drives hundreds of transitions and transfers to industry, programs of record, and the broader S&T ecosystem.

AFRL AUTHORED PUBLICATIONS IN CY20

3,251

INTELLECTUAL PROPERTY FILINGS IN FY21

86
Patents

124
Applications

83
Disclosures

AFRL FACILITIES enable its impactful research

AFRL's world-class research is enabled by its facilities and state-of-the-art capabilities. The unique nature of the Lab's work necessitates instrumentation, infrastructure, and resources not found anywhere else. Each of these sites—from the rocket propulsion test stands to the Joint DoD Supercomputing Resource Center, hypersonic wind tunnel, explosives test ranges, and a human-rated centrifuge—help AFRL and its scientists keep US forces out front, with the objective of giving the Department of the Air Force an "unfair" advantage in any fight.

ROCKET PROPULSION TEST FACILITIES

AF MAUI OPTICAL & SUPERCOMPUTING SITE

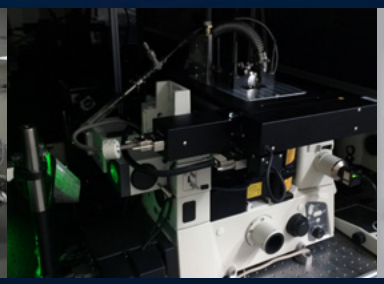
HYPERSONIC WIND TUNNEL

SENSORS COMPLEX

OUTDOOR ANTENNA TEST RANGES

STARFIRE OPTICAL RANGE

DOD'S ONLY HUMAN-RATED CENTRIFUGE



AUTONOMOUS RESEARCH SYSTEMS ROBOTIC TESTING

DOD SUPERCOMPUTING RESOURCES CENTERS

HIGH EXPLOSIVES R&D FACILITY

S&T 2030 STRATEGY CALL TO ACTION

Throughout 2021, AFRL has continued to accelerate change and enact the vision laid out by the Department's 2030 S&T Strategy. That Strategy, published in 2019 as the "S&T 2030 Strategy," was based on a study commissioned by the Secretary of the Air Force, and is central to the Lab's current and future initiatives. These exciting initiatives are discussed throughout this report.

AFRL ABIDING IMPERATIVES

- LEAD
- DISCOVER
- DEVELOP
- DELIVER

S&T 2030 STRATEGY OBJECTIVES

- Develop and deliver transformational strategic capabilities
- Reform the way S&T is led and managed
- Deepen and expand the S&T enterprise

2021 CHANGES

- Implemented pilot actions against all the S&T 2030 Strategy levels of effort
- Institutionalized the key tenets of the S&T 2030 Strategy
- Completed S&T 2030 Final Report

MOVING FORWARD

- AFRL is now postured for sustained execution and continuous innovation
- Enterprise Advisory Council and TCO will serve as organizational anchor points

AFRL is Postured for Sustained Execution and Continuous Innovation

TRANSFORMATIONAL CAPABILITIES OFFICE

A major success of the AFRL implementing the 2030 S&T Strategy has been the stand up of a cross-directorate "Transformational Capabilities Office" (TCO). TCO accelerates the changes needed to deliver the game-changing technologies that our warfighters need now and into the future. Guided by the Department's S&T strategy to cultivate leap-ahead solutions that enable the Air Force and the Space Force to dominate time, space, and complexity in all operating domains, TCO projects will deliver capabilities involving multidisciplinary solutions.

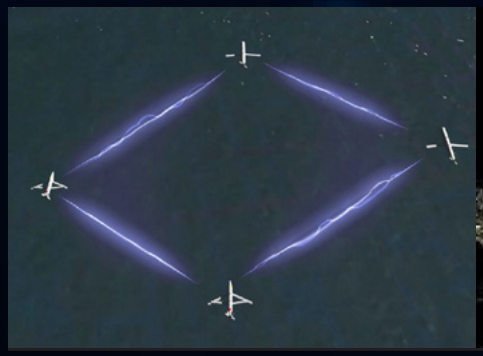
A major TCO initiative is the new WARTECH process. WARTECH provides a forum for warfighters and technologists to co-develop new operational concepts, combining S&T investments, future operating concepts, and future force design. WARTECH leverages the "Air Force Explore" solicitation and the internal Seedlings for Disruptive Capabilities Program (SDCP), to create a pipeline of bold ideas by using competition to drive cross-disciplinary collaboration and partnerships at the start of the process of technology maturation and solution development.

Air Force Explore introduces defense challenges to the national marketplace and engages with potential business partners. SDCP is an internal call for ideas, encouraging teams across multiple technology directorates to collaborate with industry and academia to execute multi-disciplinary projects to develop innovative capabilities.

WARTECH uses summits to evaluate warfighter needs and prioritize advanced technology demonstration programs. These summits have led to four AFRL programs being commissioned as "Vanguard" programs by Department of the Air Force leadership. Each Vanguard project, shown here, is described in the Impact section of this report.

READ MORE AT:
afresearchlab.com

CURRENT VANGUARD PROGRAMS



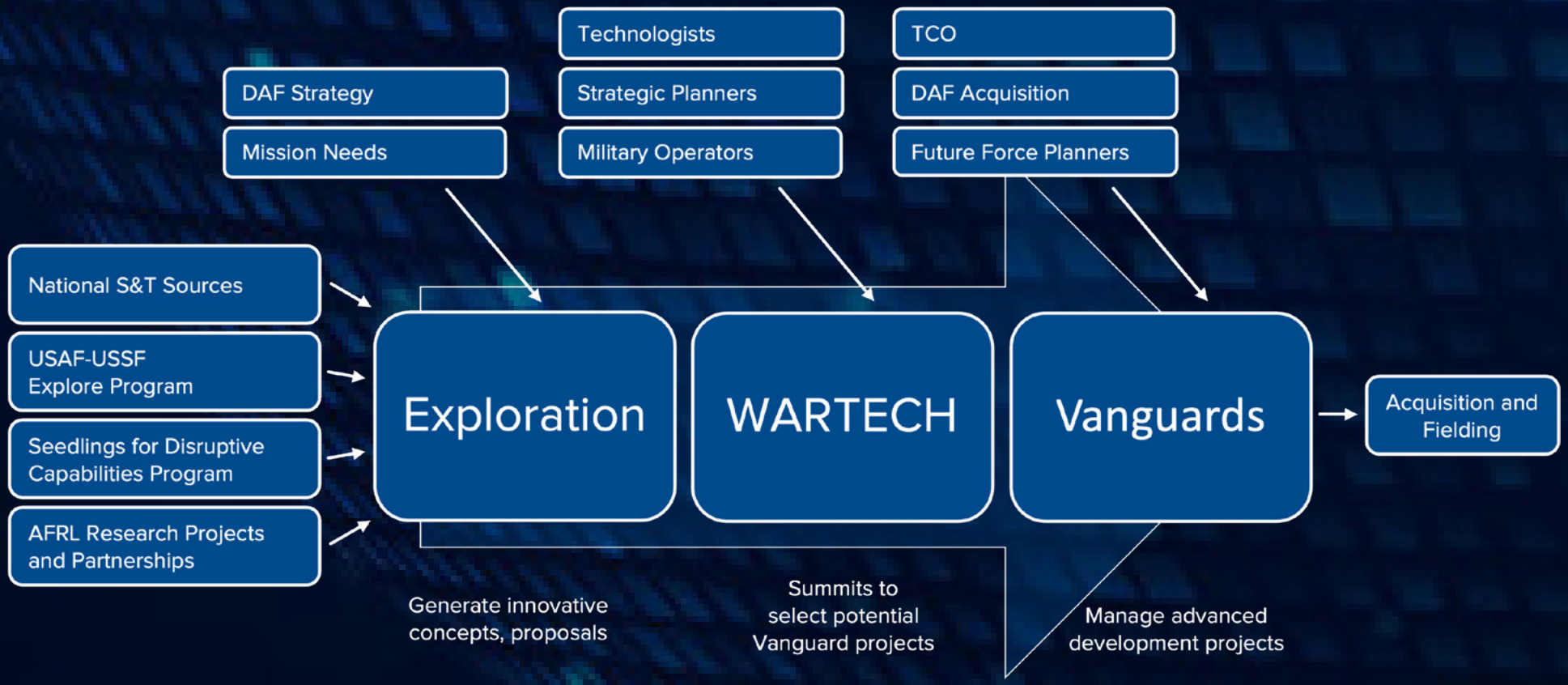
GOLDEN HORDE

NAVIGATION TECHNOLOGY SATELLITE-3

ROCKET CARGO

SKYBORG

TCO'S INNOVATION PIPELINE



"Strengthening our internal and external Air Force and Space Force partnerships will lead to better informed S&T priorities and help us ultimately deliver exceptional technologies to our warfighters."

– Major General Heather L. Pringle

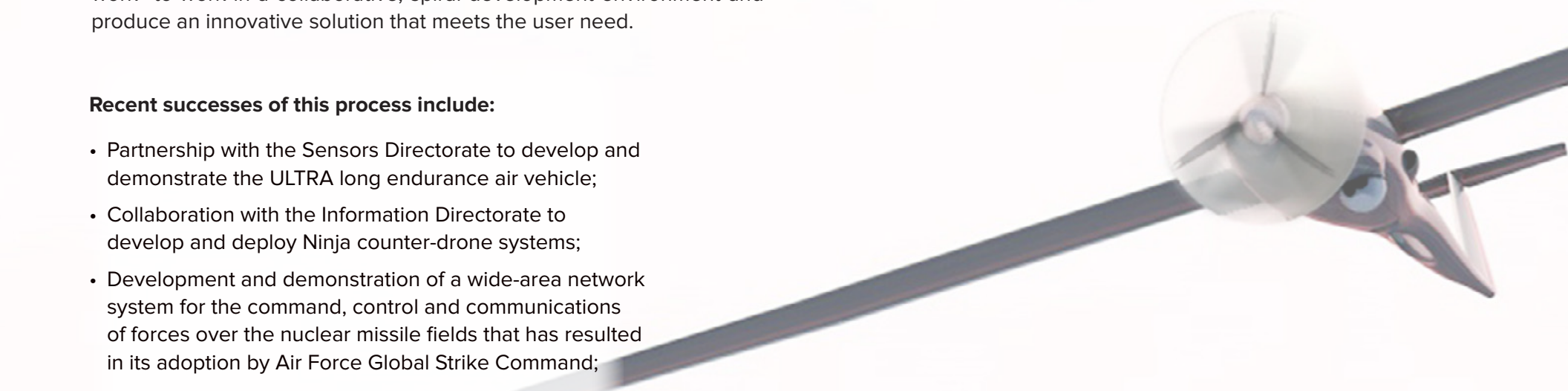
CENTER FOR RAPID INNOVATION

AFRL's Center for Rapid Innovation (CRI) supports the transition of technologies developed by the Laboratory into operational use. Focused on addressing high priority operational needs, the CRI team rapidly develops technology-enabled prototypes that can be used and transitioned into the field, typically in 18 months or less. CRI leverages the breadth and depth of knowledge within AFRL and its "innovation network" to work in a collaborative, spiral development environment and produce an innovative solution that meets the user need.

Rapidly developing and delivering such capabilities to the field ensures our Airmen and Guardians have the technological edge on every mission. CRI bridges and embodies the Laboratory's ***Lead, Discover, Develop, and Deliver*** missions—connecting our scientists' and engineers' innovation at the bench with the warfighter's needs.

Recent successes of this process include:

- Partnership with the Sensors Directorate to develop and demonstrate the ULTRA long endurance air vehicle;
- Collaboration with the Information Directorate to develop and deploy Ninja counter-drone systems;
- Development and demonstration of a wide-area network system for the command, control and communications of forces over the nuclear missile fields that has resulted in its adoption by Air Force Global Strike Command;
- Demonstration of a man-portable quadcopter with precision strike, surveillance, and load carriage capability;
- Demonstration of a low cost, long range stand-off, high accuracy, aerial delivery glider with 500lb cargo capacity that is air-dropped from C-130 or C-17;
- Development of an air-droppable unmanned Jet Ski for rescue of isolated personnel in contested environments; and
- An automated parachute activation device for Special Operations.



"We are cultivating a world-wide ecosystem of research from basic to applied that drives the pace of technology and competition in the agile pursuit of innovative solutions for warfighters and stakeholders alike."

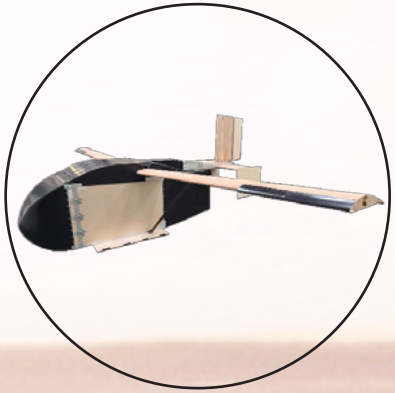
– Major General Heather L. Pringle

ROP
Wide Area
Network Node

BLADE
Small
Multipurpose
Quadcopter

A-ARC
Autonomous
Jet Ski

GRASSHOPPER
Low Cost
Supply Glider



CORAX
Automated
Parachute

AFWERX

AFWERX recently joined AFRL's diverse team of innovators. The AFWERX mission is to transition agile, affordable, and accelerated capabilities by teaming innovative technology developers with Airmen and Guardian talent from across the Department of the Air Force (DAF). AFWERX is a part of the Air Force Research Laboratory as One Lab supporting Two Services. Similarly, SpaceWERX is an organic part of AFWERX using shared processes and resources to support the US Space Force. Given the rapidly growing percentage of dual-use technologies developed outside of defense-specific requirements, harnessing the full power of American and allied innovation for competitive advantage demands a cultural transformation. The catalyst is a deliberately developed innovation corps that creates unprecedented collaboration beyond traditional networks, while reinvigorating those existing networks. To preserve enduring operational advantage, AFWERX will use this cultural transformation to both transform future operational systems and transform the multiple structures that develop and field those systems.

SpaceWERX, launched in August 2021, inspires and empowers collaboration with innovators to accelerate cutting-edge capabilities and shape our future in space. SpaceWERX forms partnerships between the military's operational experts and the top problem solvers in industry, academia, and the government. SpaceWERX uses proven AFWERX tools such as the SBIR/STTR Open Topic, the Challenge platform, growth stage investments, Spark initiatives, and the Prime program.

Ventures, the commercial investment arm of the DAF, creates simple pathways for commercial innovators and private capital investment to help the Department of the Air Force solve problems. As of 2021, AFVentures has funded over 1800 companies with SBIR/STTR funds through its "Open Topic" solicitations, 81% of which have never partnered with the DAF before.

"Unlike the past, much of the emerging technologies that will determine our future are no longer created or funded by the Department of Defense."

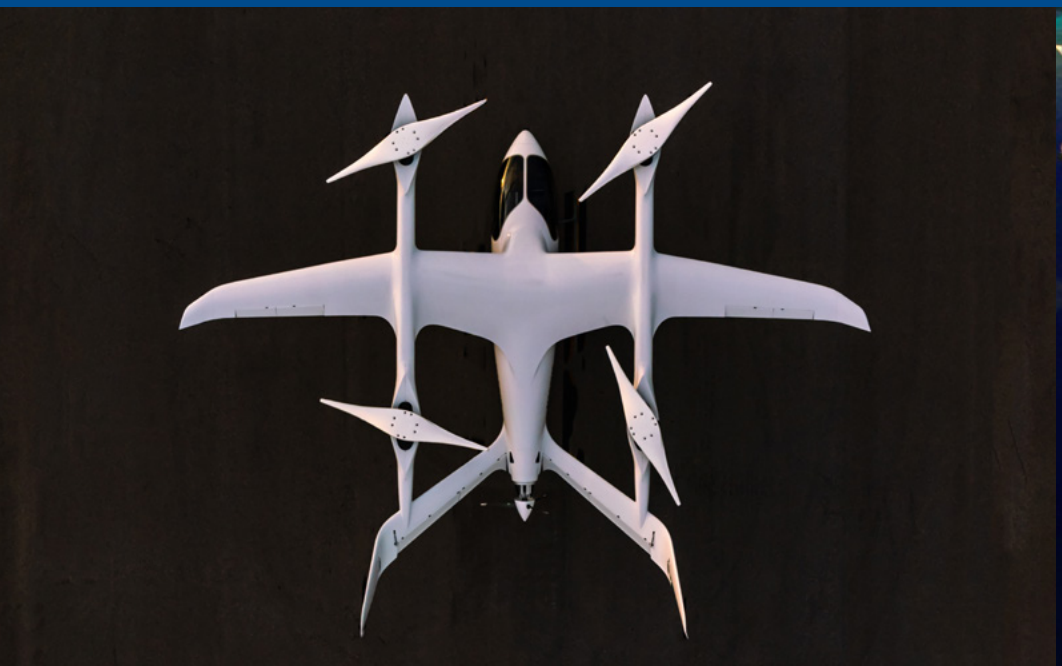
– General Charles Q. Brown
Accelerate Change or Lose

Spark connects, develops, and supports innovators throughout the Department of the Air Force. Over 80 Commander-owned, AFWERX-supported, base-level Spark Cells serve as the foundation for the DAF innovation ecosystem. These Spark Cells give voice and opportunity to Airmen and Guardians, providing the resources necessary to develop and execute locally generated ideas that increase DAF efficiency and productivity. Spark enables rapid communication and scaling across the enterprise to drive new military capabilities, effectiveness, and improve quality of life for our Airmen and Guardians.

Prime works to rapidly drive affordable capability to the field after effective technology development (e.g., Ventures) and concept engagement (e.g., Spark). Successful fielding builds trust among Airmen and Guardians as well as industry, investors, interagency partners, and international stakeholders.

The first Prime, *Agility Prime*, is the US government's first and currently only electric passenger aircraft procurement program, ensuring global leadership in the electric vertical takeoff and landing (eVTOL) aircraft market, as well as introducing the Department of Defense to zero emissions aviation. The newly announced Space Force Orbital Prime will accelerate the development and fielding of on-orbit servicing, assembly, and manufacturing capabilities. This effort will deliver new active debris remediation capabilities in the next two to four years.

READ MORE AT:
afwerx.com

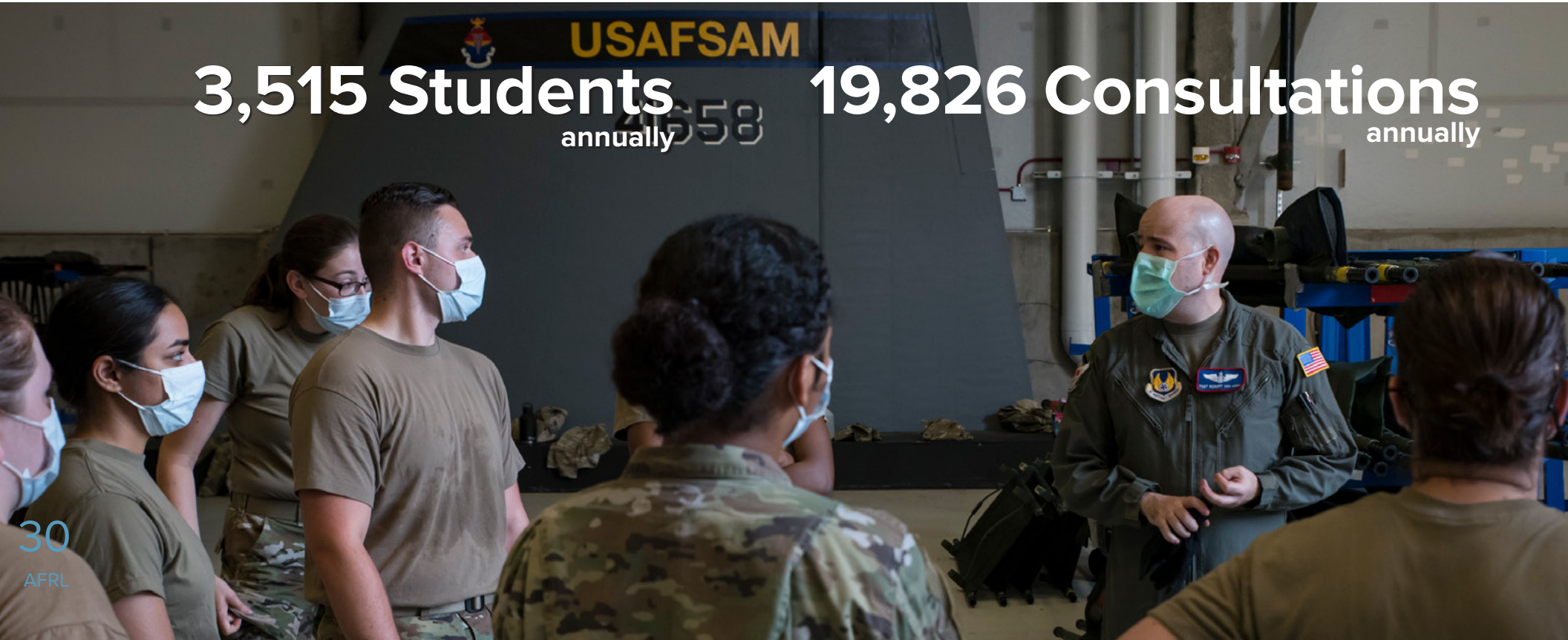


USAF SCHOOL OF AEROSPACE MEDICINE

The US Air Force School of Aerospace Medicine (USAFSAM)—part of the AFRL 711th Human Performance Wing—is an internationally renowned center for aerospace medical learning, investigation, and aircrew health assessments. AFRL proudly hosts this core mission area for the Department of the Air Force. The aerospace environment presents many unique challenges, both for those who operate the flight systems and for those who provide medical care.

Understanding the stresses that the aerospace environment puts on the human body has been core to effective operations throughout the history of US aviation and space flight. Today, USAFSAM serves as the repository and supplier of this unique medical expertise. The school trains over 3,500 students per year and assists operators and commanders via consultations in the fields of Aerospace and Operational Medicine. They promote readiness across the force using a range of tools and expertise in environmental and public health surveillance, laboratory and risk analysis, process re-engineering, and technological innovation.

These AFRL based training and diagnostic capabilities were essential to the USAF's successful response to the COVID-19 pandemic. From diagnostic testing to genetic tracking of emerging variants and ensuring that infected personnel could be safely transported home aboard USAF aircraft without risking the health of the aircrew or medical teams providing medical care during transport, the unique knowledge and capabilities of USAFSAM personnel and trainees assures the USAF mission continues across all environments.



LAB SUPPORT TO COVID-19 RESPONSE

During the COVID-19 pandemic, USAFSAM was perfectly positioned to assist in the tracking of variants to the SARS-CoV-2 virus. Because service personnel are frequently the forward-most US presence in the world, USAFSAM is able to collect "molecular intelligence" using its diagnostic and sequencing capabilities. As samples were collected for testing, the Epidemiology and Applied Technology and Genomics Labs collaborated to increase knowledge and understanding of the rapidly evolving COVID-19 public health emergency across the US government and for those in foreign deployments. By providing genetic sequences of virus samples from active-duty service members, they were instrumental in identifying early cases of novel COVID-19 variants, including the "UK Variant" (B.1.1.7), the "South Africa Variant" (B.1.351), and the "Brazil Variant" (P.1). Analysis of the small differences in each sample's genetic sequence allows researchers to construct phylogenetic trees showing the virus's evolution and to understand the lineage of emergence of variants in order to prepare for new vaccines, therapeutics, or virulent strains. USAFSAM is dedicated to discovering and disseminating the knowledge and information needed to ensure US personnel have the most up to date understanding possible as they confront the challenges posed by COVID-19.

READ MORE AT:
afresearchlab.com

TECHNOLOGY PRIORITY AREAS

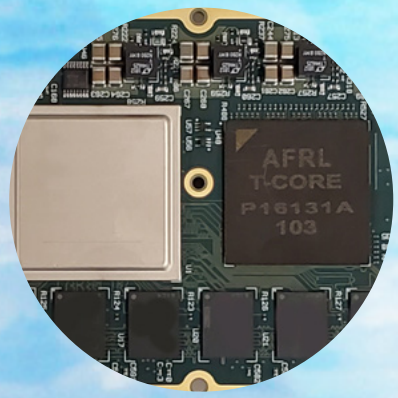
As the pace of technological advancement continues to accelerate, it is imperative that the Department of the Air Force remain at the forefront of scientific knowledge. The areas highlighted here are examples of key technological priorities for the nation representing important successes of AFRL today and areas of focus as we continue our research into tomorrow. AFRL is investing across its portfolio of programs to ensure the US, the DoD, and the DAF remain on the cutting edge in these pivotal areas.

Artificial Intelligence and Autonomy Ex. Agile Condor (pg. 44)

Rapid decision making based on data, autonomous operation of robotic systems, trusted AI

Cyber, Advance Communications, 5G Ex. Ninja (pg. 47)

Integrated secure, high bandwidth communications, control of complex systems, training using augmented reality, challenges and opportunities of 5G



Microelectronic Ex. T-Core (pg. 49)

Digital engineering, cloud computing, state-of-the-art devices, DoD operating environments

Hypersonics Ex. HAWC (pg. 56)

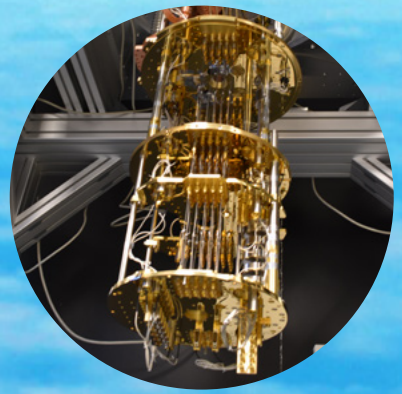
Glide vehicle technology, aerodynamics, computational fluid dynamics, materials, space vehicle design

Directed Energy
Ex. THOR (pg. 60)

High-energy laser weapons and high-powered microwave systems

Biotechnology
Ex. Project Medusa (pg. 66)

Sensing, monitoring, new materials, health and physiology protection



Quantum Information Science
Ex. Quantum Networking and Processing (pg. 74)

Timing, sensing, communications and networking, computing

AFRL IMPACT

AFRL conducts the research needed to support operations and strategic priorities across the Department of the Air Force. Here, we highlight a selection of the Lab's recent accomplishments and their positive impacts on the warfighter. These successes are organized here by the core Departmental missions they support: ensuring US **Space Superiority**; providing the US warfighter with **Information Dominance**; generating **Global Power** with a **Global Reach**; and **Discovering** the ideas that will transform far-future US capabilities.

Space Superiority

With space officially recognized as a new contested environment, effective support of the joint force requires that the US dominate space. As one Lab supporting both the Space Force and the Air Force, AFRL is pursuing research and advanced technologies to ensure that the US is the dominant force in space—whether for surveillance, space-based navigation services, or battle. The following are examples of AFRL-led research projects that will ensure US space superiority.

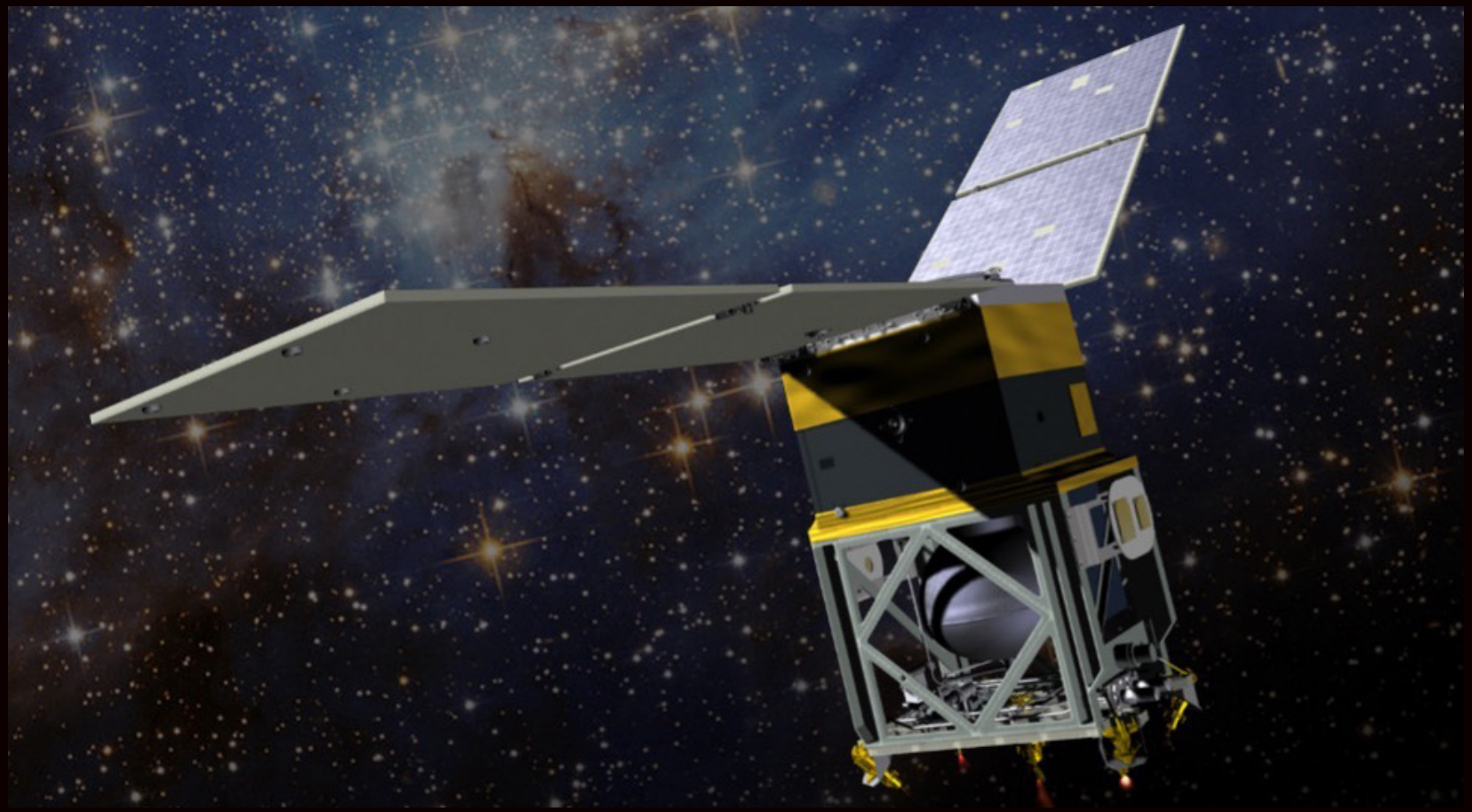
Advanced Spacecraft Energetic Non-Toxic Propellant (ASCENT)

Aerospace Systems | Air Force Office of Scientific Research

AFRL's Aerospace Systems Directorate has successfully tested a "green" propellant in conjunction with NASA as part of an on-orbit demonstration of a fueled spacecraft.

The non-toxic "green" propellant was developed by researchers in the Rocket Propulsion Division to replace the current, highly toxic hydrazine fuel that has been used to propel spacecraft for the last 50 years. The new propellant, called ASCENT, for Advanced Spacecraft Energetic Non-Toxic propellant, is derived from energetic ionic liquids developed with basic research funding from AFOSR in the 1990s. ASCENT has a higher propellant density and increased efficiency over hydrazine leading to a 15-50% increase in absolute maneuver capability. By eliminating the enormous safety risks to ground personnel posed by hydrazine, ASCENT green propellant is simplifying and streamlining ground operations, thereby reducing both the cost and schedule impact of propellant loading and spacecraft integration efforts. AFRL, in partnership with Space Systems Command, NASA, and others, continues to work with the domestic propulsion industry to mature this technology and enhance the mobility of future USSF space assets.

READ MORE AT:
afresearchlab.com



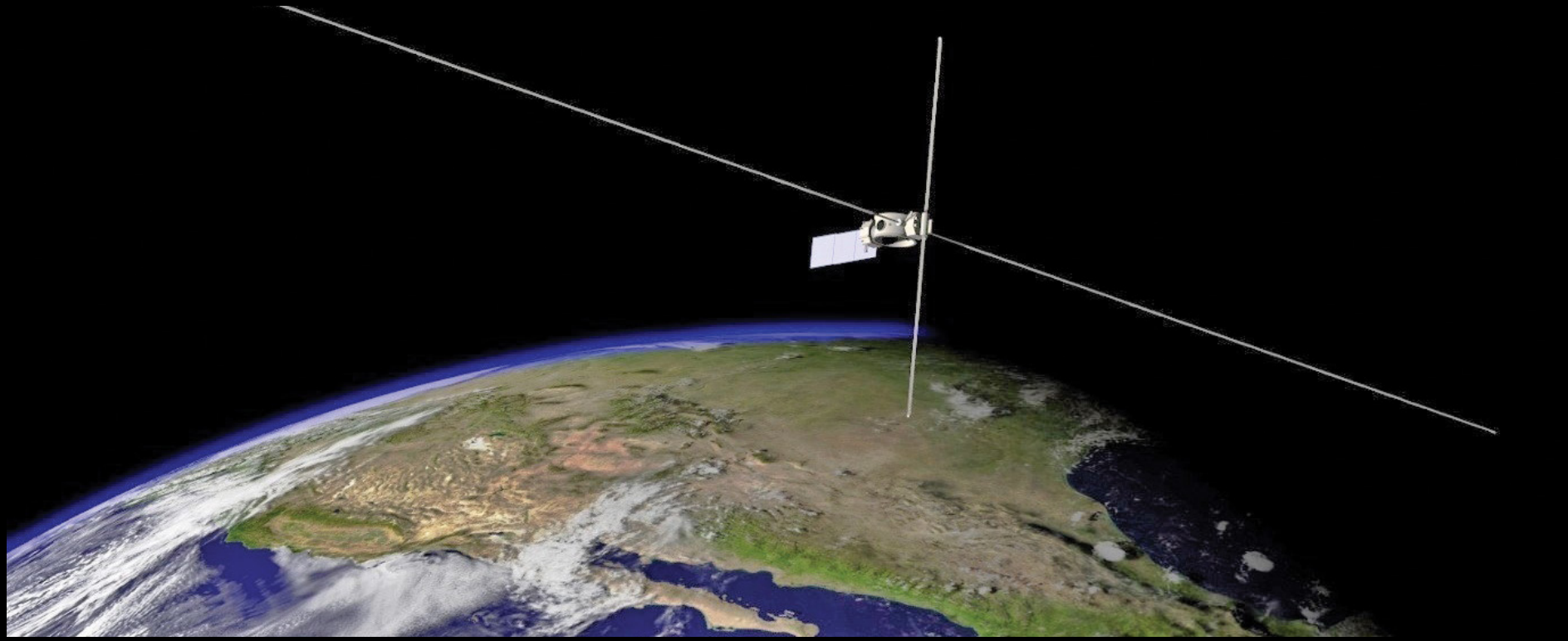
Demonstration and Science Experiments Satellite (DSX)

Space Vehicles

Since the dawn of the Space Age, researchers in AFRL's Space Vehicles Directorate have studied the radiation belts surrounding Earth. Particular interest has been paid to trapped radiation eminating from a High-Altitude Nuclear Explosion (HANE), which has posed an asymmetric threat to our space capabilities for decades. The injection of massive numbers of electrons into the space environment from such an event would cause worldwide communication disruptions and severe damage to low Earth orbit spacecraft critical to civil, commercial, and military activities. The ability to rapidly remediate the space environment after a HANE would provide a game-changing deterrence and recovery option, reducing the likelihood and effectiveness of such an attack.

Thanks to the Demonstration and Science Experiments (DSX) spacecraft, our under-standing of Earth's natural radiation belts and approaches to deal with HANE events has expanded greatly. Launched by a commercial rocket as part of the DoD's Space Test Program in 2019, AFRL's DSX spacecraft completed it's mission in mid-2021 conducting over 1,300 active experiments while in orbit to study the interaction of very low frequency radio waves with trapped radiation. The lead for AFRL's Radiation Belt Remediation effort, Dr. Michael Starks, explains that DSX represents a critical enabler toward HANE protection and remediation technology, while providing new insights into how the natural Van Allen belts impact satellite health. Starks said: "This is a huge contribution to understanding how the space environment affects our spacecraft and how we can protect against harmful effects."

READ MORE AT:
afresearchlab.com



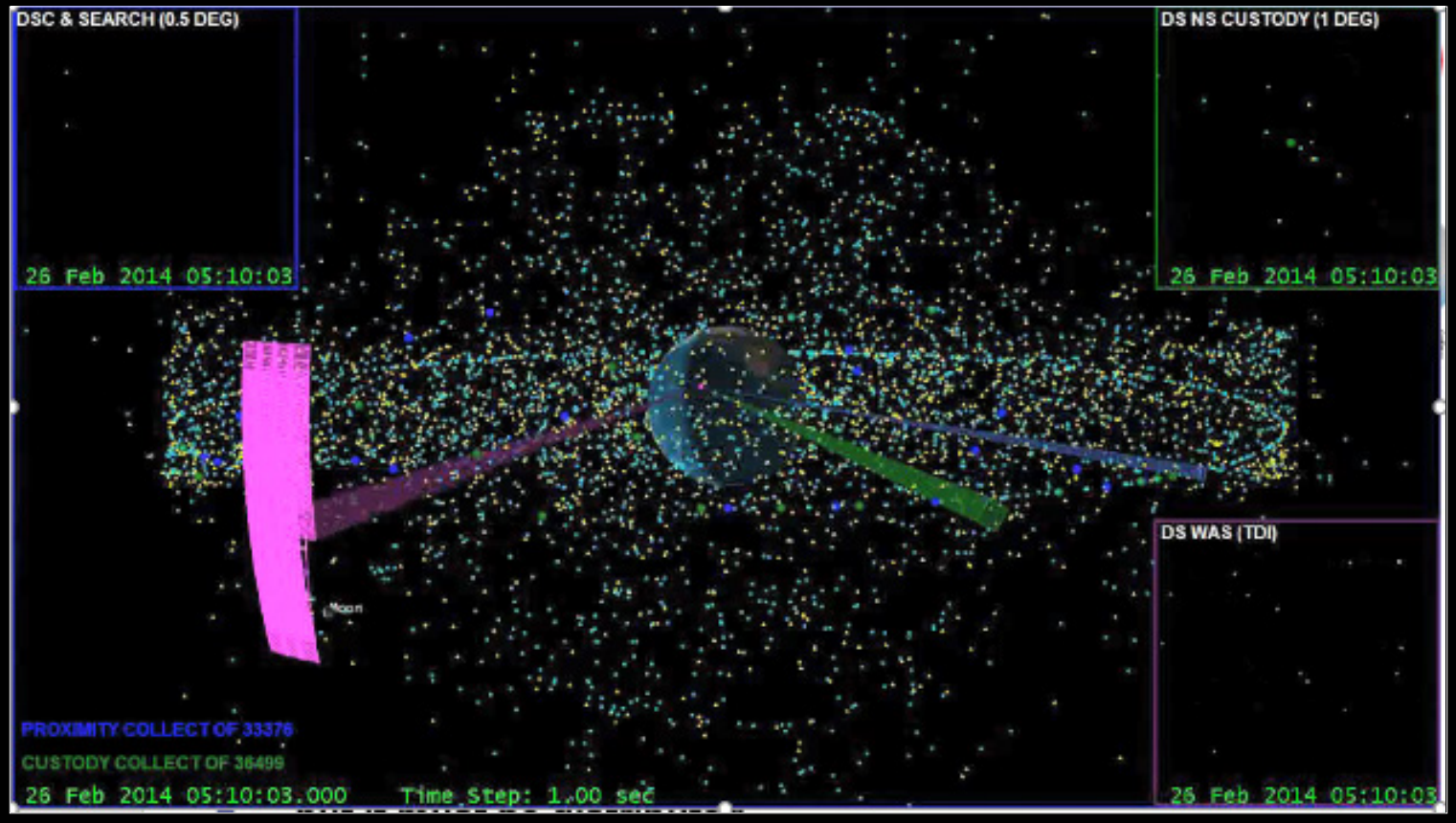
Dynamic Optical Telescope System (DOTS)

Directed Energy

Located in Hawaii as part of the Maui Space Surveillance System, the AFRL Joint Capability Technology Demonstrator (JCTD) program to develop the Dynamic Optical Telescope System (DOTS) has graduated this year, maturing technologies to perform autonomous tasking and control of a family of ground-based optical telescopes. DOTS is designed to discover potentially threatening spacecraft in geosynchronous orbits, track those discovered objects, and provide follow-up characterization to understand their nature and status.

DOTS employs different classes of telescopes to perform wide-area searches, track objects for orbit determination, and provide spacecraft characteristics. DOTS is an autonomous system designed to operate at a rapid cadence, closing the custody loop on a list of known spacecraft of interest as well as newly-discovered objects throughout the night sky. The DOTS technology is robust enough to handle multiple maneuvering objects simultaneously.

DOTS provides the Department of the Air Force and its partners the ability to discover new space objects in geosynchronous orbits over the Pacific and detect changes in the orbital trajectories or operational states that could put US satellites at risk in that geographic area. DOTS technology is extensible to multiple geographic sites and even space-based Space Domain Awareness architectures. Transition of DOTS technology to new systems and architectures is underway.



High g-Force Training for Space Flight

711th Human Performance Wing – USAF School of Aerospace Medicine

AFRL's USAF School of Aerospace Medicine (USAFSAM) is collaborating with NASA to pave the path for the nation's space travelers to return to the moon. That journey, ushered via NASA's Artemis missions, is another step USAFSAM has taken over its robust history of helping prepare current and future astronauts for the rigors of human space flight. Specifically by operating the DoD's only high g-force centrifuge certified for humans, USAFSAM is helping astronauts understand and condition themselves for the considerable g-forces they will experience during the launch and recovery sequences of future space flights. Understanding the unique impact of the aerospace environment on human physiology is core to USAFSAM's mission and expertise—a clear contribution to NASA's endeavor, in collaboration with commercial and international partners, to establish a future long-term presence on the moon.

READ MORE AT:
afresearchlab.com

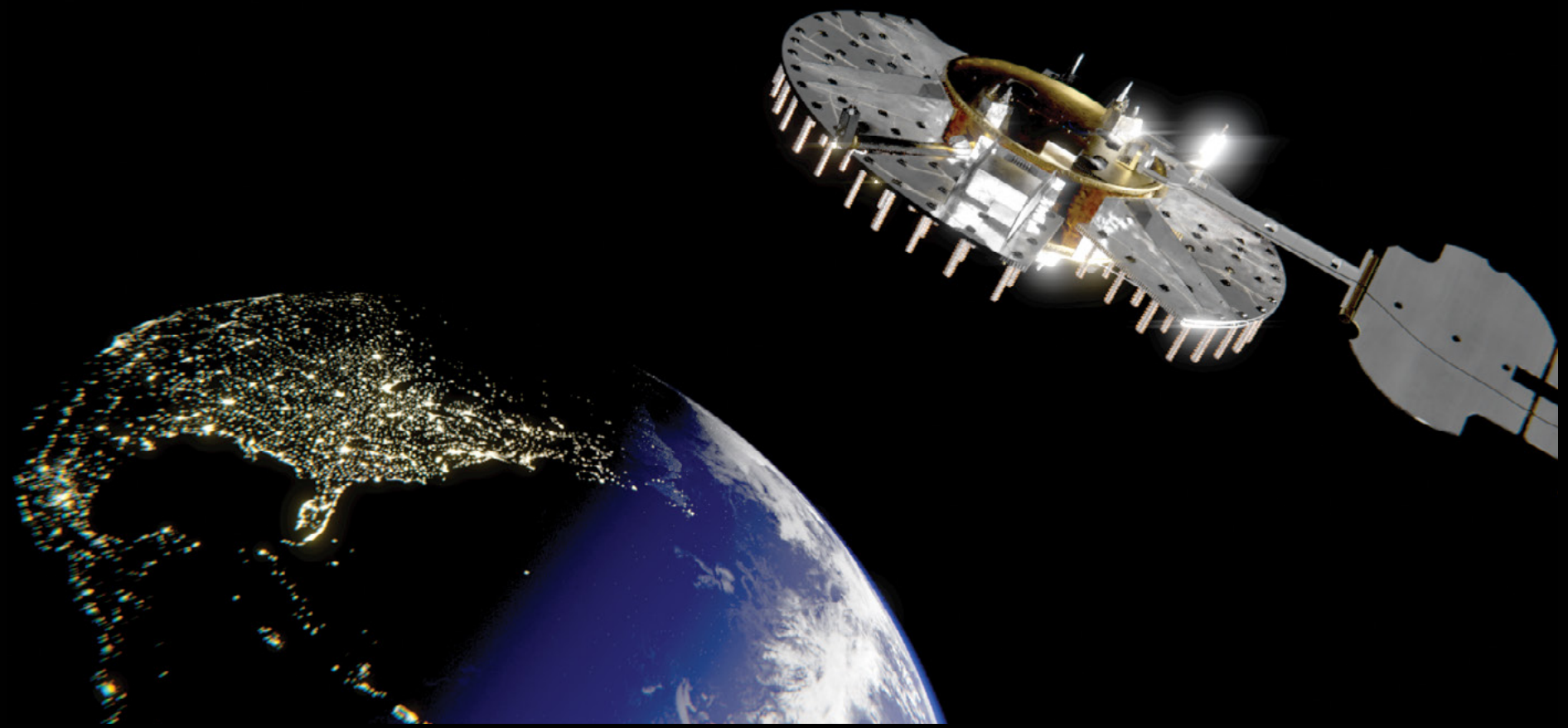
Navigation Technology Satellite-3 (NTS-3)

Transformational Capabilities Office

The US Space Force's Global Positioning System (GPS) constellation provides unprecedented position, navigation, and timing (PNT) accuracy to the warfighter. Since the inception of GPS, space-based PNT has become a global utility that undergirds a wide range of commercial and military applications. Air traffic control, banking, farming, and cellular networks all depend on uninterrupted GPS coverage, and it is a key enabler for virtually all US and allied military operations.

Set to launch in 2023, Navigation Technology Satellite-3 (NTS-3), America's first experimental satellite navigation system in over 45 years, will push the boundary of today's PNT capabilities to pave the way for a more flexible, robust, and resilient architecture. AFRL is working with industry to develop advanced techniques and technologies to detect and mitigate interference to PNT capabilities and augment GPS to increase system resiliency for military, civil, and commercial users. To test these new capabilities in hardware, software, and concepts of operations, NTS-3 will operate for at least one year in geosynchronous orbit. Ultimately, NTS-3 will identify key design considerations for new GPS receivers that incorporate multiple signals and readily adapt to warfighter needs.

READ MORE AT:
afresearchlab.com

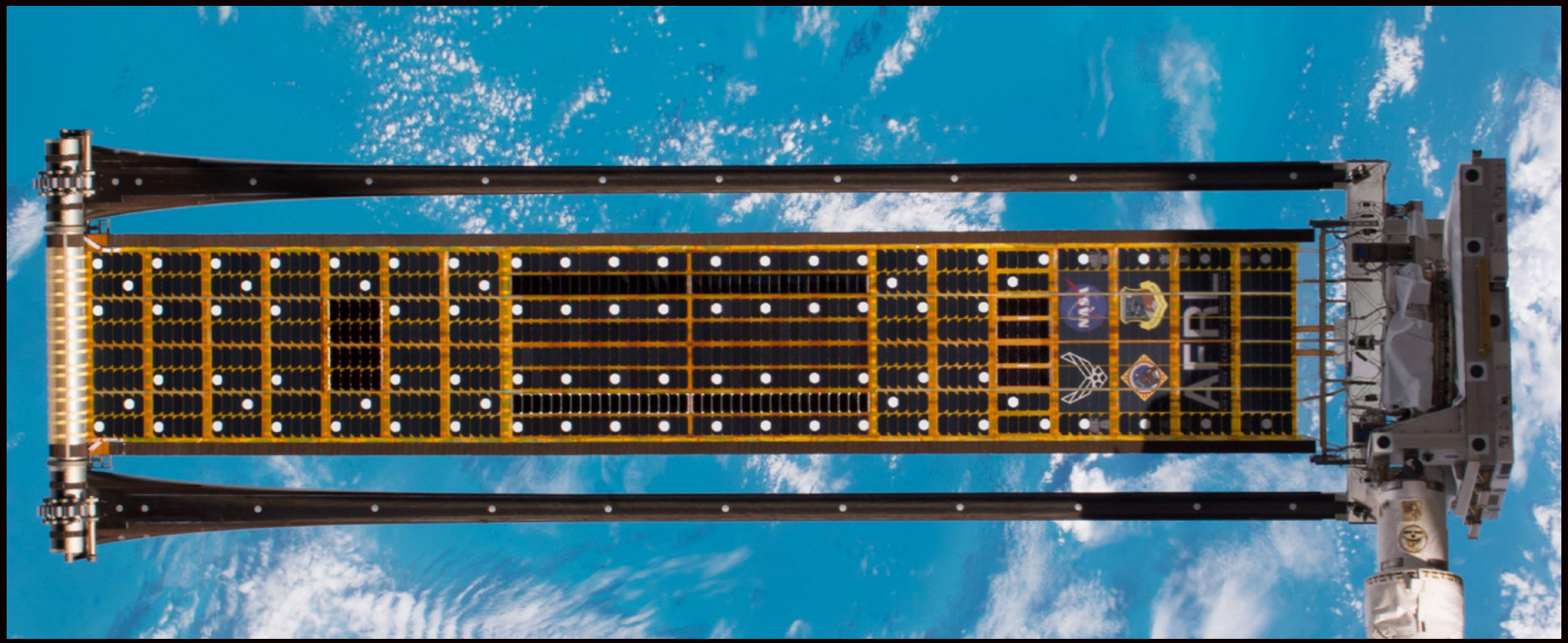


Roll-Out Solar Arrays (ROSA)

Space Vehicles

Since the successful flight demonstration of the Roll-Out Solar Array (ROSA) on the International Space Station in 2017, ROSA, developed at AFRL's Space Vehicles Directorate, has proven itself multiple times in space, with more deployments to come. In 2021, AFRL's industry partner for ROSA deployed two International Space Station ROSA (iROSA) wings on orbit, with four more set to deploy in 2022—resulting in a critical 20-30% increase in power delivered to the station. Not limited to deployment on the current space station, ROSA is slated for the commercially developed and operated Orbital Reef. Reaching further into the solar system, two ROSA wings were deployed on NASA's Double Asteroid Redirect Test (DART) spacecraft in the end of 2021, supporting a mission aimed at proving an Earth-saving impact-style technique to alter the trajectory of an asteroid. At a geostationary Earth orbit, ROSA will power a broadband communications satellite set to launch in 2022. On the moon, ROSA will supply NASA's Lunar Gateway Power and Propulsion Element with the needed power to support long-term lunar human presence. Providing up to 30kW per wing and as much as 400kW in a Mega-ROSA configuration, coupled with its excellent packing density, the ROSA technology continues to enable and enhance space missions.

READ MORE AT:
afresearchlab.com



University Nanosatellite Program (UNP)

Air Force Office of Scientific Research | Space Vehicles

Since the beginning of the space age, AFRL's Air Force Office of Scientific Research (AFOSR) basic research investments have defined the art of the possible for space operations. For over 20 years, AFOSR, in conjunction with the AFRL Space Vehicles Directorate, has administered the University Nanosat Program (UNP) to train and educate university students and future space professionals to design, build, launch, and operate small satellites. The UNP is a nationally recognized program with its own funding line in the President's Science, Technology, Engineering, and Math Education Portfolio. The UNP has equipped thousands of students across the country with foundational spacecraft systems engineering skills. To date, over 38 universities have been involved with 8 successful launches and 15 small satellite builds.

In 2021, the solicitation to universities included the additional opportunity for an institution to collaborate with AFRL's Space Solar Power Incremental Demonstrations and Research (SSPIDR) project. This innovative project is focused on studying space-based power collection and transmission. The winning participant will contribute and help launch experiments into space to test new high efficiency energy collection capabilities using deployable solar cells, radio-frequency beaming technology, and beam shaping and focusing technologies to transmit power safely to ground collection sites. Results of the SSPIDR project will enable military forward operating bases, and other installations worldwide, to be powered by energy collected in outer space.

READ MORE AT:
afresearchlab.com

Information Dominance

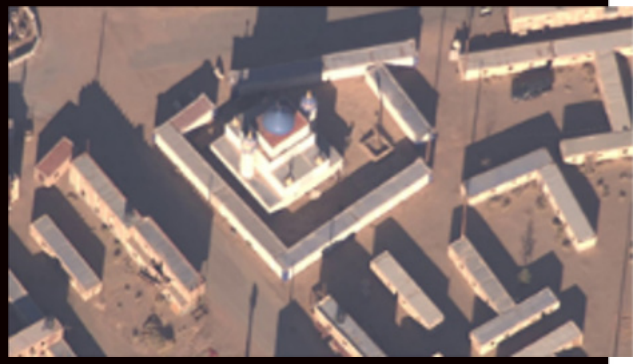
Information dominance implies connecting the elements of the joint force, ensuring that all allied forces on the battlefield and in command centers have timely access to the information that they need, and that data is processed into actionable information at speed. The following are examples of research projects that AFRL leads to ensure information dominance.

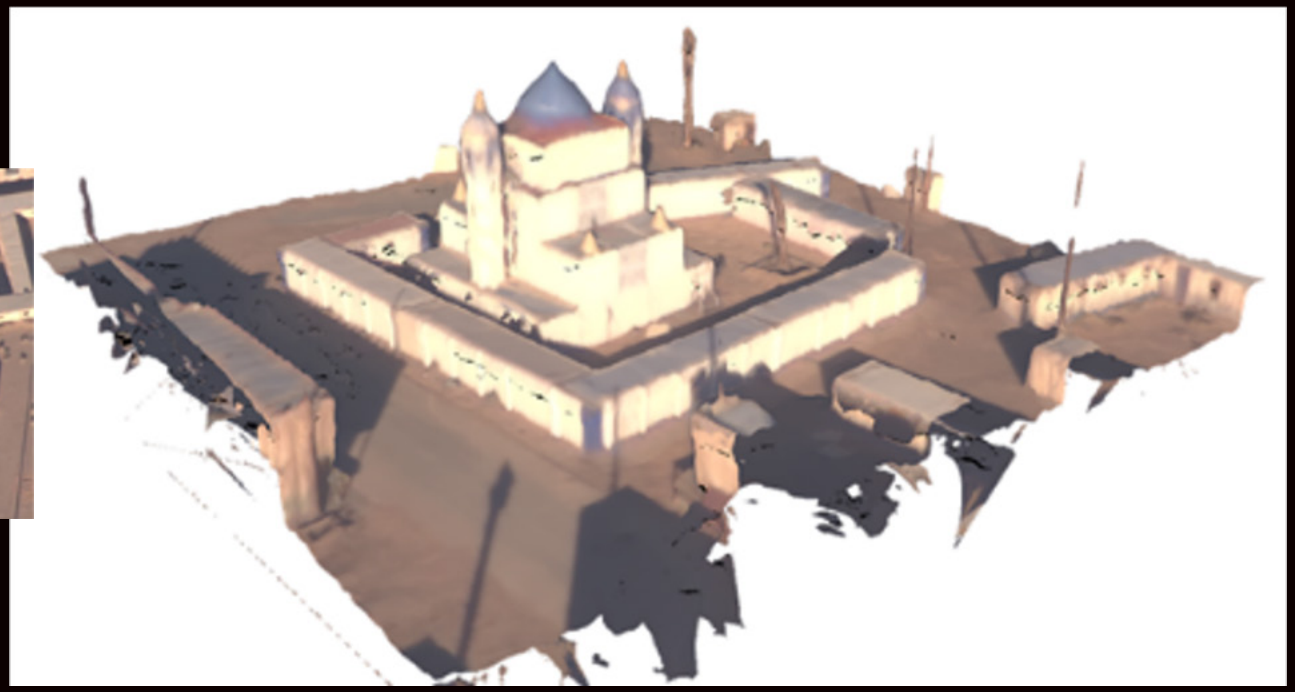
3D Models of Terrain and Objects

Sensors

To operate throughout the world and to support combat missions, the Air Force requires high fidelity maps and a good understanding of the terrain, buildings, and structures that characterize the operational environment. Recent work at AFRL, in conjunction with small businesses and industry, has led to the ability to construct detailed 3D models in real time as airborne platforms operate in remote regions. Researchers and AFRL scientists have developed techniques to make use of lidar, video, and radar data to build terrain models that provide detailed 3D representations of the ground, buildings, and structures that overlay the earth.

These rapidly constructed 3D renderings enable comparison with prior models to determine changes, including subtle ones, that might be significant for operations. These techniques are made more accurate by using multiple sensor types and by accessing prior information. An understanding of the topography and local structures in the battlespace provides the military with new capabilities to support combat operations.





Agile Condor

Information

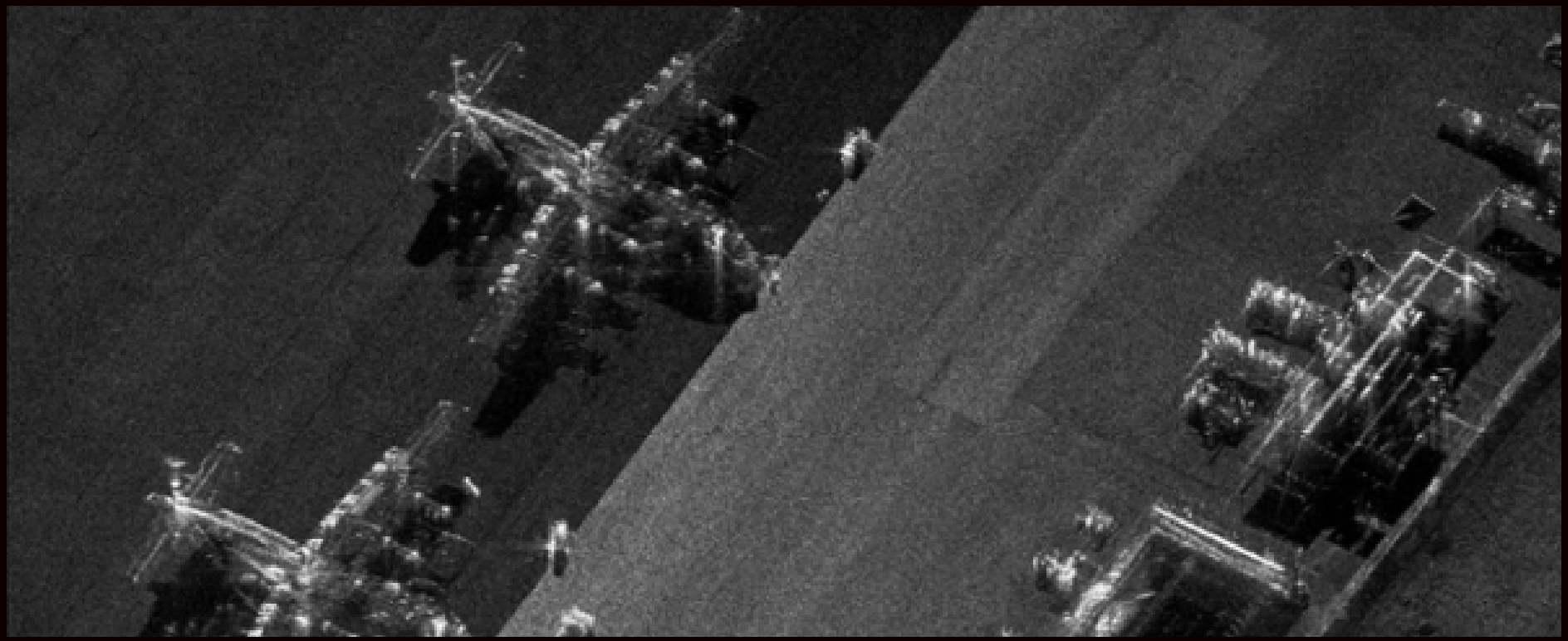
Researchers in the AFRL Information Directorate developed the Agile Condor system, consisting of hardware, software, and flexible algorithms to perform on-board automated target recognition using machine learning technology. It can be trained to filter potential targets in images formed from visible light, infrared, and/or radar data, thus requiring less bandwidth for communicating images to ground personnel for target confirmation and less input from human analysts to identify targets. Agile Condor brings rapid and autonomous target recognition to the tactical edge. The system is light-weight, low-power, and provides supercomputer processing capabilities. It can be fielded either podded or internal to a fuselage on a variety of platforms to include the MQ-9, as shown here in a podded system. Agile Condor was successfully demonstrated in airborne exercises and tests during 2021 to include Northern Edge 21 as part of the Air National Guard's Ghost Reaper and the Joint Artificial Intelligence Center's Smart Sensor program.

Automatic Target Recognition using Synthetic Aperture Radar

Sensors

While flying thousands of feet above the ground, US Air Force assets are tasked with finding and locating objects of interest or objects that might become threats. These might be missiles and their transporters, military vehicles, air defense units, launch pads and launch support equipment, or newly created fixed buildings, hideouts of terrorists, or other infrastructure that might represent significant activity. The targets might be fleeting, obscured, or disguised. Recognizing and identifying them is a key Air Force function. Using sensor systems developed over decades and integrated into manned and unmanned Air Force platforms, researchers have developed ways of identifying objects from images, video, laser, and radar data. These systems are increasingly automated, making use of models of the target objects.

AFRL researchers have guided the development of these automated techniques, collaborating with US entrepreneurs, researchers, small businesses, and defense industries to predict signatures of objects of interest and rapidly search for these targets in sensor data collected by Air Force platforms. Different sensors are important for different object types, and AFRL's tradition of working with synthetic aperture radar imagery, using sophisticated radars, is important to operations when clouds and weather conditions make it difficult to use other sensor types. Recent progress has enabled these processing capabilities to be integrated into operational platforms.



Confined Space Monitoring System

711th Human Performance Wing – Airman Systems | Materials & Manufacturing

AFRL's Airman Systems Directorate has partnered with small business to refine and market the Confined Space Monitoring System for use in both the military and commercial sectors. This effort, recently transitioned with the launch of a new company, addresses the often-complex hazards associated with working in small spaces.

Confined space operations are currently required for the maintenance of all military aircraft. These actions range from inspecting the interior of an aircraft wing to performing repairs on a fuel tank. The Confined Space Monitoring System incorporates wearable safety equipment to monitor the condition of the maintenance personnel, providing important early warning of environmental hazards. The Airman Systems Directorate helped to mature the technology, conducting tests on a C-130 aircraft wing using redesigned components to be worn inside tight workspaces.

In collaboration with the AFRL Materials & Manufacturing Directorate and an industry consortium, they developed a flexible arm band with an environmental air quality monitor that is durable, fireproof, and comfortable to wear. The technology has been commercialized and is improving worker safety in both military and commercial environments.

READ MORE AT:
afresearchlab.com

Ninja

Information | Center for Rapid Innovation

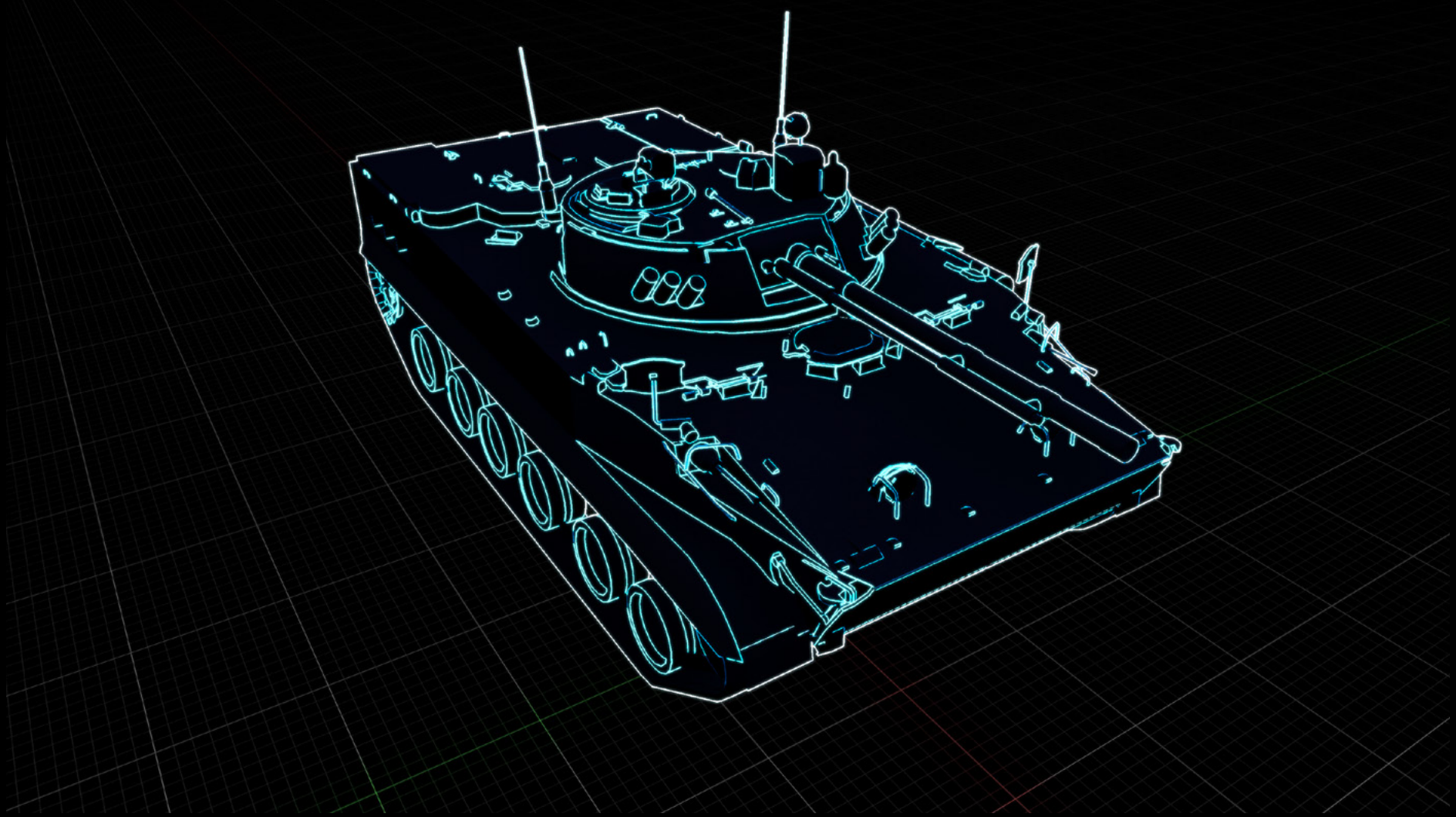
Developed by researchers within AFRL's Information Directorate in conjunction with the Center for Rapid Innovation, Ninja is a highly scalable electronic warfare anti-drone air defense system. Rather than shoot an adversarial drone out of the air, risking the lives of anyone below, or deploy broad-spectrum anti-drone technologies, Ninja is able to precisely identify an unknown or unfriendly drone and hone in on the platform. The Ninja system then uses a suite of advanced cyber and electronic warfare capabilities to take over control of the threatening drone. The Ninja operator can then safely land the vehicle, retain its position in the air, or even reroute the aircraft and "return to sender."

The Ninja system is currently operationally deployed by the military and other government partners. It can be used for domestic security at sports events or for extra security at venues for international conferences. In coming years, every US Air Force installation could be defended by a Ninja system.

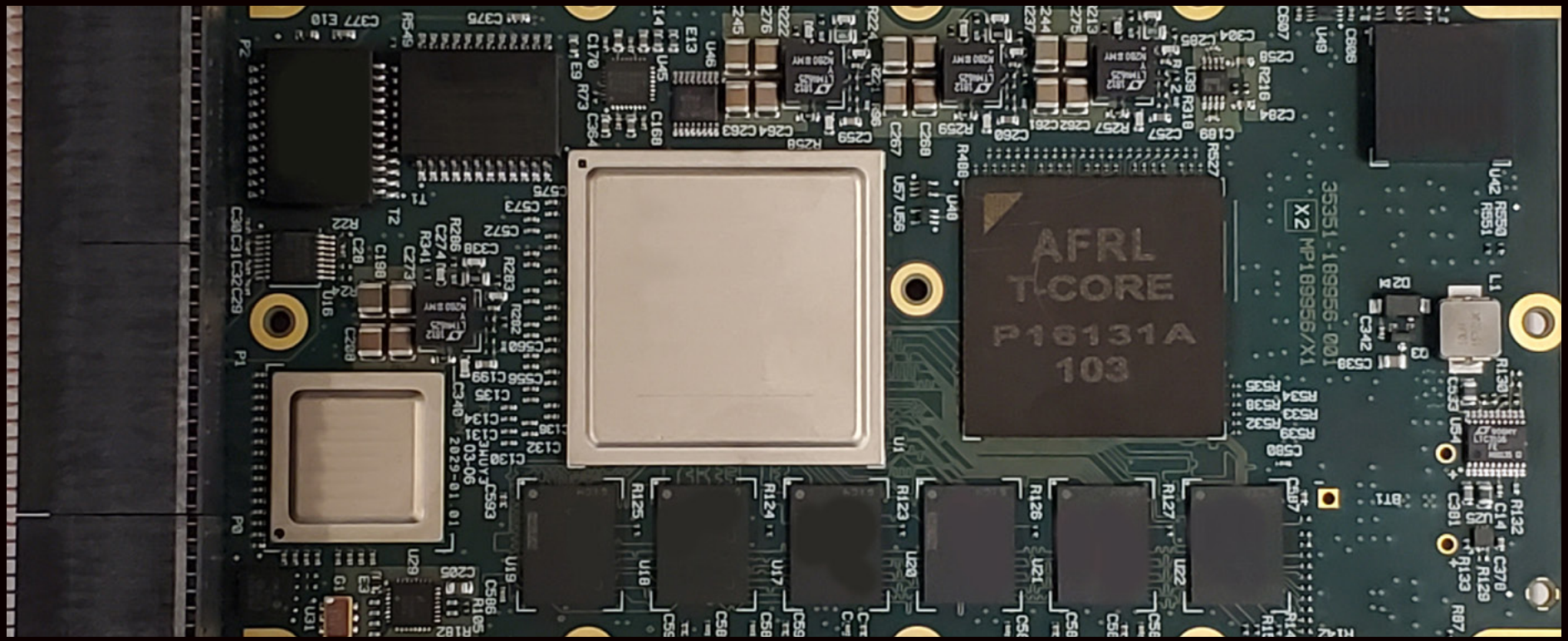
Rapid Target Insertion

Sensors

Sometimes, models of new kinds of target types must be inserted into an operational system quickly. Building on rapid model insertion technology developed over years of research, AFRL has recently transitioned capabilities to enable the rapid insertion of three-dimensional models of new target types into operational systems to enable the automated recognition of these objects. In this way, automated recognition systems can be adapted quickly and tailored to the class of objects to be identified.



The AFRL Information Directorate has designed a highly secure microprocessor using in-house expertise, working in partnership with other government agencies, such as the Defense Microelectronics Activity, AFRL was able to manufacture the custom-designed microelectronics chip in onshore facilities. In the illustration, the large dark square on the right is the AFRL T-Core microprocessor, which provides ultra-high security from the possibility of hacking or execution of malicious code. The government-owned design provides military-grade security, and the single-board computer using the T-Core has been flight tested. T-CORE could be applied to many critical Infrastructure systems.



Tactical Assault Kit Ecosystem (TAK ECOSYSTEM)

Information

TAK (Tactical Assault Kit) is a software system, with a mix of open source and unlimited rights, initially developed by AFRL's Information Directorate to provide access to georeferenced imagery and communications tools for military users. The TAK ecosystem allows users to overlay and align different sources of data with map data. This permits data sharing, visualization of elevation data, and target management through a suite of user developed plug-ins and applications. With TAK, teams can overlay their own position with aerial imagery, communication feeds, target positions, weather information, and more. Today the TAK ecosystem is operated by over 300,000 military, civilian, and partner nation users, working on over 20 different programs of record, making it *the* accessible situational awareness solution in the field. The success of the TAK ecosystem has led to the creation of the TAK Product Center managed by US Army Combat Capabilities Development Command.

READ MORE AT:
afresearchlab.com

Ultra-Long Endurance Aircraft Platform (ULTRA)

Sensors | Center for Rapid Innovation

The Ultra-Long Endurance Aircraft Platform (Ultra) consists of a high-performance, cost-effective, commercial airframe converted to a fully automated system with customized surveillance sensors and autonomous takeoff and landing capabilities. Leveraging previous experiences with un-crewed aerial vehicle (UAV) systems, the Center for Rapid Innovation modified a commercial motor-glider to support remotely piloted operations. Ultra has a customizable suite of intelligence, surveillance, and reconnaissance (ISR) tools that provide for dramatically extended missions at affordable costs. A series of flight tests began in 2019 at Dugway Proving Ground, Utah, resulting in a 2 1/2-day continuous flight demonstration in December 2020. Ultra has since been deployed globally to enhance warfighter operations.

READ MORE AT:
afresearchlab.com

Global Power

The Air Force and Space Force can bring to bear awesome power anywhere in the world to gather information, prosecute threats, and ensure US national security by projecting influence. AFRL supports the development of the next generation of weapons and munitions to project power while minimizing unwanted effects. The following are examples of research and projects that AFRL leads to ensure US ability to project global power.

Dialable Effects Munition (DEM)

Munitions

The Air Force Research Laboratory's Munitions Directorate concluded its Dialable Effects Munition (DEM) demonstration program with a test of the experimental weapon in July 2021. As a Joint Capability Technology Demonstration, the DEM provides technologies that enable a weapon's effects to be tailored dynamically in flight. This will give the Air Force the ability to select munition effects based on three critical mission areas: an Area Attack effect that detonates high above the target for maximum dispersed effects over the area where collateral damage is not an issue; a Precise Lethal Footprint effect that detonates lower over the target to confine effects to a small area for low-collateral damage; and a Surface Target Perforation effect that detonates after the weapon punches through a structure.

The precise lethal footprint attack and the weapon's perforation capability have been successfully demonstrated. The DEM fusing, explosives, warhead, and sensors have transitioned to several Air Force weapons programs in acquisition development phases and one ACAT II weapon program where they are already increasing effectiveness and survivability. According to Maj. Gen. Pringle, the technology has the potential to simplify the sizes and types of weapons needed at the forward edge of the battlefield, which leads to a more efficient, less costly support tail.

READ MORE AT:
afresearchlab.com

Golden Horde

Transformational Capabilities Office

Golden Horde is developing and demonstrating Networked Collaborative and Autonomous (NCA) weapon technology designed to create a "swarm" of munitions. The capability allows various weapons to share data, interact, develop, and execute coordinated behaviors. Current weapons generally fly a pre-designated route based on prior targeting, which cannot adapt when circumstances change. The first phase of Golden Horde demonstrated the Collaborative Small Diameter Bomb-I (CSDB), the first NCA capability on inventory Air Force weapons. CSDB utilized the SDB-I in three live flight demonstrations to perform collaborative formation flight, geolocate jammers, conduct synchronized target impacts, and reassign weapon target assignments based on in-flight target updates sent to the swarm after launch. The second phase of the Golden Horde program is developing the Colosseum: a high fidelity, government owned, virtual environment to develop, test, and evaluate NCA technology and tactics—providing a computational way for innovators and warfighters to "try before they buy." The Golden Horde Colosseum will provide the acquisition community with a baseline digital engineering environment and enable researchers to drive technology development forward more efficiently, with the ability to test NCA technologies for future weapon programs almost as fast as they can imagine them. These research outcomes will become transformational warfighting capabilities through the Program Executive Officer for Weapons.

READ MORE AT:
afresearchlab.com

High Energy Laser Weapon System (HELWS)

Directed Energy | Strategic Development Planning & Experimentation

AFRL's Strategic Development Planning & Experimentation (SDPE) office engaged the Directed Energy Combined Test Force (DE CTF) to characterize the technical performance parameters of two HELWS and then to conduct field operational assessments of each to determine operational effectiveness and evaluate suitability and sustainability for use in an operational environment.

With a low cost-per-shot, high energy laser systems provide an affordable and viable option to protect military and critical infrastructure by rapidly defeating threats. Lasers offer a nearly infinite number of shots, minimal logistics, and precision accuracy with very low-collateral damage, making them an attractive alternative to traditional munitions.

READ MORE AT:
afresearchlab.com

Hypersonic Air-breathing Weapon Concept (HAWC)

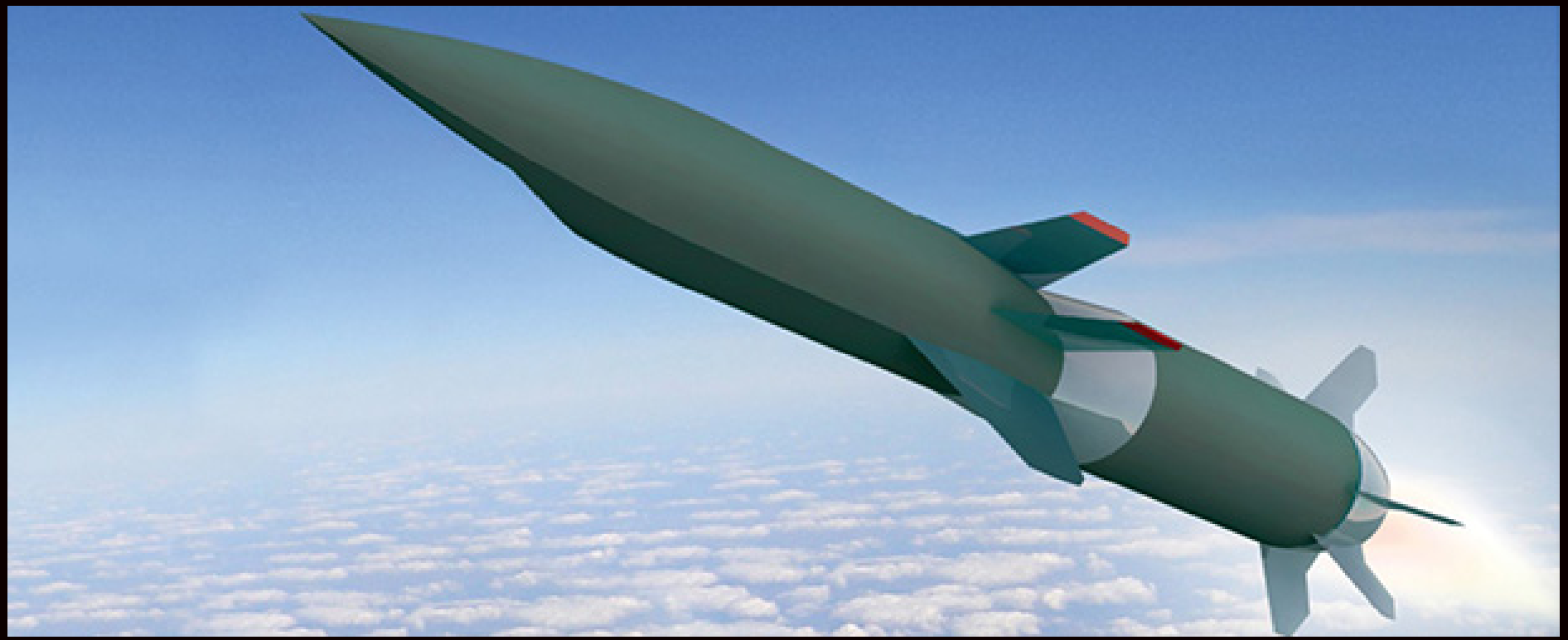
Aerospace Systems | Munitions

AFRL's Aerospace Systems and Munitions Directorates have been working collaboratively with DARPA on the Hypersonic Air Breathing Weapon Concept (HAWC) project. One of the possible designs completed a free flight test in September 2021.

The cruise missile is released from an aircraft and a rocket boosts the vehicle to hypersonic speeds where its scramjet engine kicks in. The scramjet propels the cruiser to a speed greater than Mach 5. The HAWC vehicle can strike targets far more quickly than traditional cruise missiles and has significant kinetic energy even without high explosives. The goals of the test were to demonstrate vehicle integration and the release sequence, safe separation from the launch aircraft, booster ignition, velocity increase, booster separation and engine ignition, and cruise. All primary test objectives were met.

These achievements build on decades of pioneering hypersonic technology developments across AFRL.

The HAWC project is but one of multiple efforts with AFRL as a major participant supporting the research and development of hypersonic vehicles.



XQ-58A (VALKYRIE)

Aerospace Systems

AFRL's Aerospace Systems Directorate has continued to demonstrate and advance the capabilities of affordable, high performance unmanned air vehicles through its Low Cost Attritable Strike Demonstration program. In a first for the XQ-58A Valkyrie platform, it released a payload from the internal weapons bay during its 6th flight, successfully launching a smaller ALTIUS-600 unmanned aircraft system. In addition to releasing a payload, the Valkyrie expanded its operational envelope by flying higher and faster than the previous flights.

This test further demonstrates the utility of this new performance and cost class of UAVs that the Aerospace Systems Directorate continues to develop.

READ MORE AT:
afresearchlab.com

Miniature Self Defense Missile (MSDM)

Munitions

AFRL's Munitions Directorate developed the concept of the Miniature Self-Defense Munition (MSDM) to kinetically kill an adversaries' anti-aircraft missile using a small air-launched munition that would intersect the incoming threat before it reaches its target. The primary purpose of the MSDM is to provide self-defense capabilities to high value aerial assets. The concept was matured and designs were developed using contracts with major defense partners.

Instead of luring away incoming missiles using chaff or other diversions, the MSDM intends to destroy a surface-to-air anti-aircraft missile by striking it while in flight. A highly maneuverable airframe and automated seeker help guide the MSDM to its moving target for interception. Because the MSDM is so small and lightweight, multiple missiles can be carried on a fighter jet, giving the aircraft greater protection in contested environments.

Skyborg

Transformational Capabilities Office

Skyborg is a Vanguard program developing a system of technologies to allow un-crewed aerial vehicles (UAVs) to operate alongside human-piloted aircraft or other UAVs in support of important joint force missions. Skyborg integrates autonomy software with un-crewed systems, allowing UAVs to team with crewed aircraft and provide teammates with key data to support rapid, informed decisions at relevant speeds. With multiple un-crewed teammates, a human pilot will have better awareness of the environment and threats, and thus greater survivability on combat missions. A partnership between AFRL, the Air Force Life Cycle Management Center, Air Force Futures, and Air Combat Command, Skyborg is designed to progress from design through prototype to fielding.

Technologies in Skyborg's Autonomy Core System range from simple algorithms to autonomous flight controls, and include functions that can accomplish defined tasks or subtasks in a mission. The Air Force is transitioning the science and technology investments and operational experimentation efforts from Skyborg to a future program for collaborative aircraft via the Program Executive Officer for Fighters and Advanced Aircraft.

READ MORE AT:
afresearchlab.com

Tactical High Power Operational Responder (THOR)

Directed Energy | Air Force Office of Scientific Research | Strategic Development Planning & Experimentation

Over the years, AFRL and other military research organizations have repeatedly leveraged basic research advances in high-power magnetrons and beamforming technologies. With technical roots tracing back to Air Force Office of Scientific Research funded programs of the 1980s, today's researchers in the Directed Energy Directorate have integrated modern magnetron technologies in the Tactical High Power Operation Responder (THOR) system. THOR is an electromagnetic weapon to defeat swarms of drones that might present a threat to airbases. To meet the threat from adversaries' aerial vehicles, AFRL researchers constructed the THOR's high-power microwave system to defeat multiple small UAVs simultaneously. THOR is a transportable and rapidly deployable system that can non-kinetically defeat threats, at distances of tactical significance, with a low cost per shot. AFRL progress continues on the first-ever extensive overseas field assessment of THOR as part of the Air Force Strategic Development Planning & Experimentation (SDPE) Office's Directed Energy Weapons Experimentation Campaign.

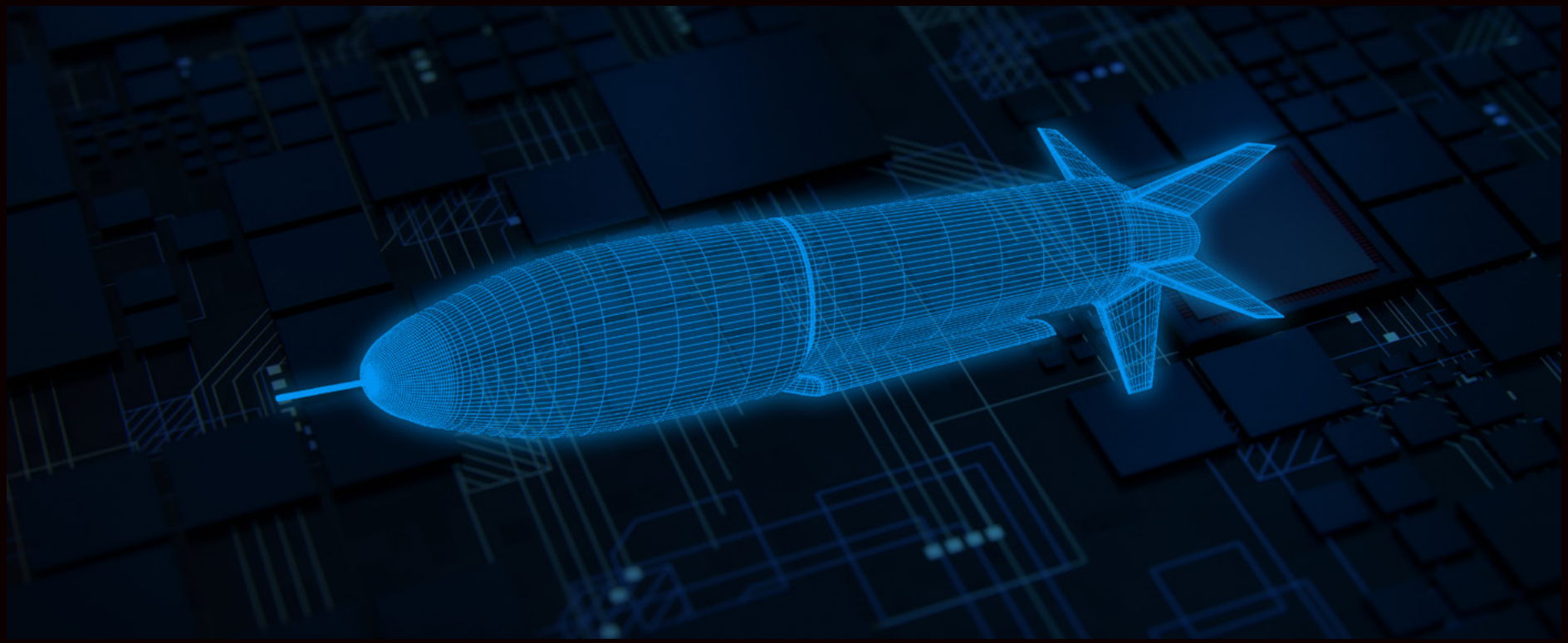
READ MORE AT:
afresearchlab.com

WeaponONE for Digital Design

Munitions

Under the Weapons Digital Enterprise WeaponONE program, the Air Force Research Lab Munitions Directorate created a digital twin of the Gray Wolf missile, a prototype low-cost cruise missile that could be deployed in swarms to counter enemy air defenses, to aid in the development of advanced cruise missiles. The process of creating a digital doppelganger, for which the Gray Wolf was chosen as an initial exemplar, is the essence of the WeaponONE program. Digital design, when done properly, allows for engineering, testing, and optimization processes to be conducted far more rapidly and at lower costs in a virtual space using high performance computing systems. The digital Gray Wolf design was tested in a demonstration in early 2021.

READ MORE AT:
afresearchlab.com



Global Reach

The Air Force and Space Force are unique in that they can reach any part of the globe within hours, and sometimes within minutes. Further, they can sustain operations in any part of the globe by delivering supplies when and where needed, or by transporting people to and from distant locations. AFRL supports the forces by maintaining and improving US capabilities for global reach. The following are examples of research projects that AFRL leads to ensure that the US has superior capabilities in global reach.

Aircraft Atmosphere

711th Human Performance Wing – Airman Systems | Materials & Manufacturing | HPCMP

The close, enclosed quarters of an aircraft cabin presented a uniquely challenging operating environment during the COVID-19 pandemic. Due to the Laboratory's broad expertise, AFRL researchers were able to rapidly develop an improved COVID-19 decontamination protocol, especially for the Department's workhorse fleet of C-17 transport aircraft. Building on their experience developing the Joint Biological Agent Decontamination System (JBADS), researchers developed a simple, new, and low-cost decontamination strategy using readily available ground heaters and custom built "humidity rings" to help kill the SARS-CoV-2 virus in the aircraft environment. Meeting the needs of Air Mobility Command (AMC), this new decontamination method will be implemented for widespread field use.

AFRL researchers made use of the AFRL supercomputer capabilities (the HPCMP) to study the complex airflows within the cabins of traveling aircraft. This research enabled US Air Force operations to safely transport passengers suffering from COVID-19 without incurring unjustifiable exposure risk to the crew flying the aircraft. AFRL researchers specializing in human health, air flow, aircraft systems, and supercomputing were able to collaborate to provide multidisciplinary solutions and resources to aid airmen in the field.

READ MORE AT:
afresearchlab.com

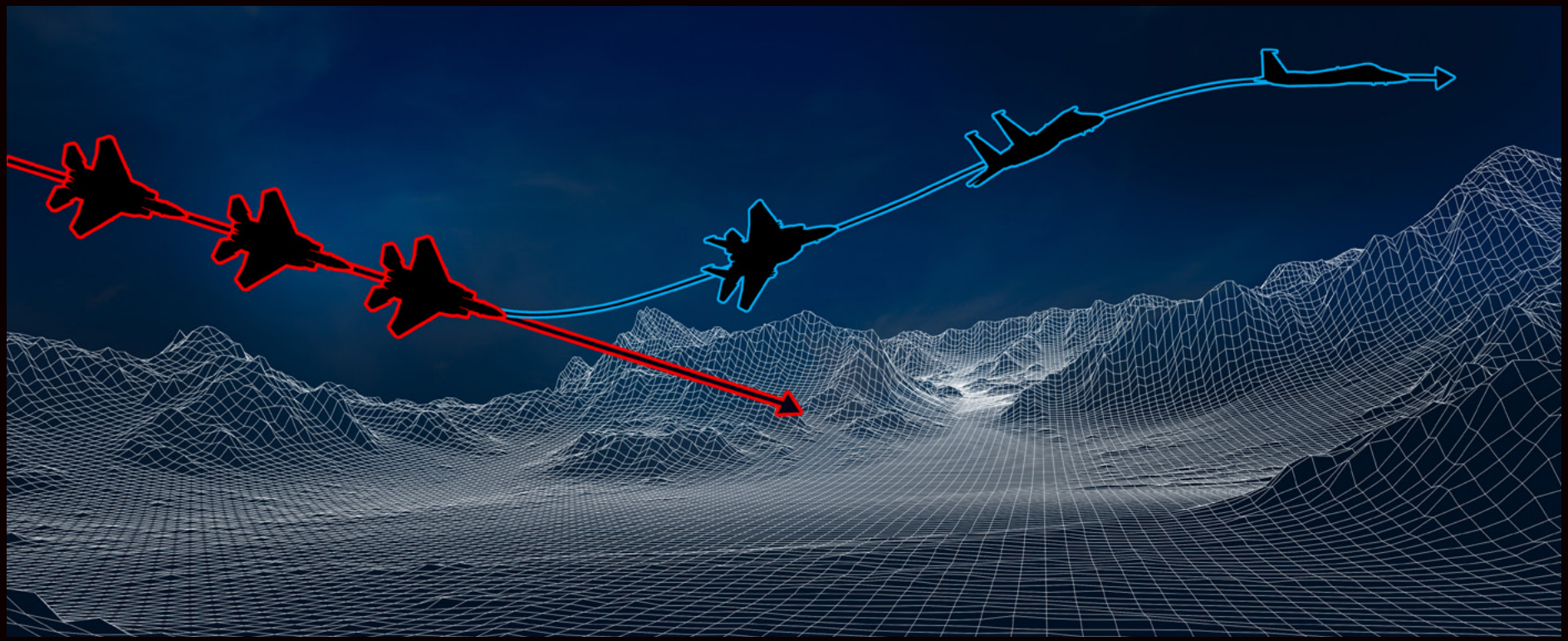
Automatic Ground Collision Avoidance System (AUTO GCAS)

Aerospace Systems

A recent investigative report from the National Commission on Military Aviation Safety (NCMAS) concerning military aviation safety has recognized the work of the Automatic Collision Avoidance Technology team from AFRL's Aerospace Systems Directorate and the successful transition of its Automatic Ground Collision Avoidance System (Auto GCAS). Developed in conjunction with NASA and defense contractors, Auto GCAS was designed to protect pilots from crashes known as "controlled flight into terrain."

The system consists of a complex set of collision avoidance and autonomous decision-making algorithms that utilize precise navigation, aircraft performance and on-board digital terrain data to determine if a ground collision is imminent. It can then direct an autonomous avoidance maneuver—a roll to wings-level and +5g pull in some cases. No action is required by the pilot, though the system does have a pilot override function. The system has already saved 11 lives and 10 aircraft demonstrating that autonomy is emerging as the new frontier in aviation and safety.

READ MORE AT:
afresearchlab.com



Cockpit Laser Eye Protection

Materials & Manufacturing

In recent years, the adversarial use of lasers has become an increasing threat to aircraft crews, on the battlefield, and in commercial and general aviation. While AFRL has been on the front line, providing laser eye protection (LEP) solutions for the military for the better part of 20 years, they recently transitioned a custom-LEP solution to a civilian law enforcement group.

While effective, most LEP technology works by filtering out green or red light (the most common colors for lasers) but can also therefore make it difficult for pilots to read flight instruments that use similarly colored lighting. To solve this problem AFRL's Personnel Protection Team in the Materials and Manufacturing Directorate developed an advanced LEP design for military and commercial use, called CALI (Commercial Aviation Low Intensity). CALI protects crews from laser assault while also allowing them to continue to operate aircraft without disruption—especially important in critical phases of flight.

READ MORE AT:
afresearchlab.com

Project Medusa – Biocementation

Materials & Manufacturing

Researchers in AFRL's Materials and Manufacturing Directorate have collaborated with a North Carolina-based small business to develop biomanufacturing processes to rapidly expand austere airfields using common agricultural chemicals and natural resources (soil and water) found at the location. These processes significantly reduce the need for heavy equipment, large teams of civil engineers, and large quantities of cement and other materials to be shipped to site. Instead, it allows bacteria to transform the local soil into hardened "biocement" by creating calcium carbonate crystals and binding together the soil. This will allow US forces to build infrastructure in otherwise resource poor locations and operate from locations that were previously inaccessible. Once US forces have finished using the airfield, the hardened earth can easily be returned to its original state, lessening the ecological impact of overseas deployments of military personnel.

Biomanufacturing and "biocement" will enable tomorrow's US Air Force to project power and realize their Global Power and Global Reach missions. This capability is made possible by the expertise of AFRL Materials & Manufacturing researchers working to translate the commercial developments to meet the special needs of the military.

Rocket Cargo

Transformational Capabilities Office

Pushing on the boundary of the possible, this AFRL Vanguard study, Rocket Cargo, is assessing the viability of leveraging commercial rockets to ship supplies around the world. With the aim of putting cargo containers onto rockets, each carrying a payload comparable to that of the service's current C-17 workhouse, the concept would provide the ability to fly supplies to remote areas in just minutes instead of hours or days. In partnership with USTRANSCOM, Space Force Futures & Integration, Air Force Futures, and the Space Systems Command, Rocket Cargo aims to prove that rocket-based transport of cargo is viable, and that it is adaptable enough to provide agile logistics. Beyond improving the safety and efficacy of front-line resupply under fire, Rocket Cargo could serve in situations such as disaster relief, humanitarian assistance, and provisioning remote bases and outposts.

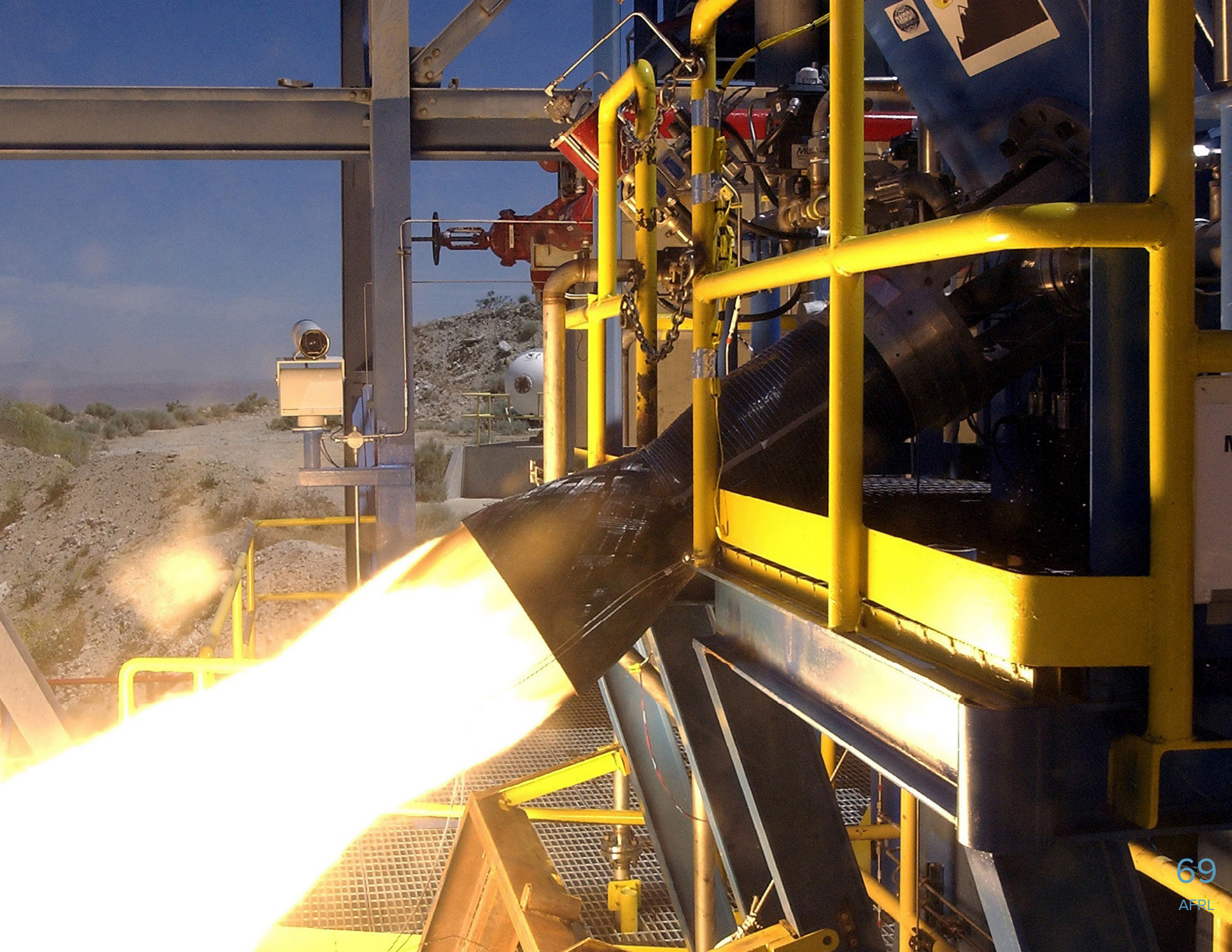
READ MORE AT:
afresearchlab.com

Transportation Isolation System and Negatively Pressurized CONEX Training (TIS/NPC TRAINING)

711th Human Performance Wing – USAF School of Aerospace Medicine

The Transportation Isolation System (TIS) and Negatively Pressurized CONEX (NPC) are infectious disease containment units that allow for in-flight medical care of patients afflicted by contagions like COVID-19 while minimizing risk to aircrew and medical attendants. Medical professionals from the USAF School of Aerospace Medicine (USAFSAM) are training medics on using the TIS, and now primarily the newer and larger NPC, to safely move patients affected by COVID-19 aboard military cargo aircraft. The TIS and NPC are important operational tools that the Air Force provides the joint force, via Air Mobility Command and subsequently US Transportation Command, to safely transport patients afflicted by contagious pathogens around the globe. First implemented after the Ebola virus outbreak in 2014, the TIS was engineered to ensure patients get the proper treatment in the event they become infected with any contagious disease during missions in affected areas. The NPC significantly increases the number of patients, 23, that can be safely transported in a single aircraft compared to the TIS, 4. USAFSAM ensures that our Airmen and Guardians know how to make full use of the technologies at their disposal, such as NPC and TIS, to maximize operational success and return patients home safely.

READ MORE AT:
afresearchlab.com



Discover

The US has been the world's leader in science and technology research for many decades. Research offers possibilities to support multiple mission areas for the Department of the Air Force, and basic research discoveries are critically important to the development of future Air Force and Space Force capabilities. AFRL maintains a robust portfolio of projects supporting cross-cutting research. The following are examples of research and projects driven by AFRL that will advance future capabilities across Air Force and Space Force missions.

Leadership of Basic Research

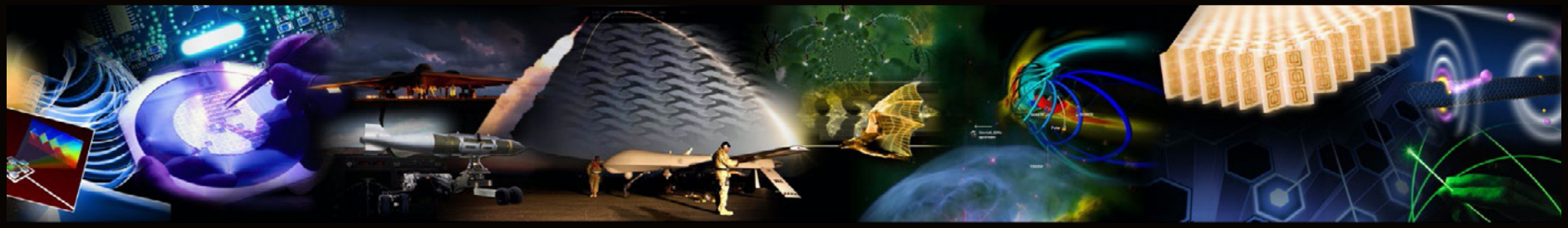
Air Force Office of Scientific Research

Air Force Office of Scientific Research (AFOSR) advances scientific knowledge through its leadership and management of the Department of the Air Force's basic research program. AFOSR funds high-risk, high-reward research with the potential to change the world and focuses on advancing the United States Air Force and Space Force warfighting capabilities. The Directorate's portfolio includes 82 Nobel laureates at last count, most of whom received funding decades before winning the prestigious prize. By supporting such research endeavors, AFOSR drives the Department of the Air Force and keeps warfighters plugged in to the game-changing technologies of tomorrow. AFOSR has a huge span of influence, leveraging relationships developed with the world's best academic researchers and institutions.

AFOSR's efforts are driven by its more than 60 world class research project managers at 5 global locations, each of whom are experts in their scientific fields of study. Domestically, AFOSR manages over 1,300 basic research projects across the country at more than 200 universities and small businesses in 47 states. Internationally, AFOSR maintains over 300 global partnership projects in over 40 countries. AFOSR ensures the United States continues to lead the world in advanced technology development by championing critical basic science and engineering research while also building the country's next generation of scientific leaders.

READ MORE AT:
afresearchlab.com

40+ Countries | **Nation-wide** | **60+ Program Managers** | **82 Nobel Laureates** | **200+ Universities** | **300+ Global Partnerships** | **1,300+ Basic Research Projects**



Autonomous Research System (ARES)

Materials & Manufacturing

The Autonomous Research System Operating System (ARES OS) is an open-source operating system, pioneered by AFRL to make materials science research faster and more effective. ARES can design and carry out experiments, answer research questions, and analyze results, using artificial intelligence and machine learning enabled “research robots” to direct and conduct autonomous, closed-loop research orders of magnitude faster than currently possible. The ARES “robots” learn along the way, finding and using the best, most effective methods for experimentation and for collecting and analyzing data and results, thereby improving human researchers’ time use and task efficiency. By teaming with ARES, human scientists can spend more time focused on complex and difficult research problems, using the OS to run more experiments faster and with methods best suited to support broad research goals.

ARES OS is accelerating change for the Air Force and its partners across the scientific community. For example, 3D printing has rapidly reshaped aerospace manufacturing by enabling new design paradigms and reducing lead time for hard-to-source spare parts. Notably, the ARES OS has helped make strides in accelerating the efficiency of 3D printing processes, overcoming the limitations of multiple manual calibrations thereby saving time and materials historically lost to failed calibrations performed by human operators.

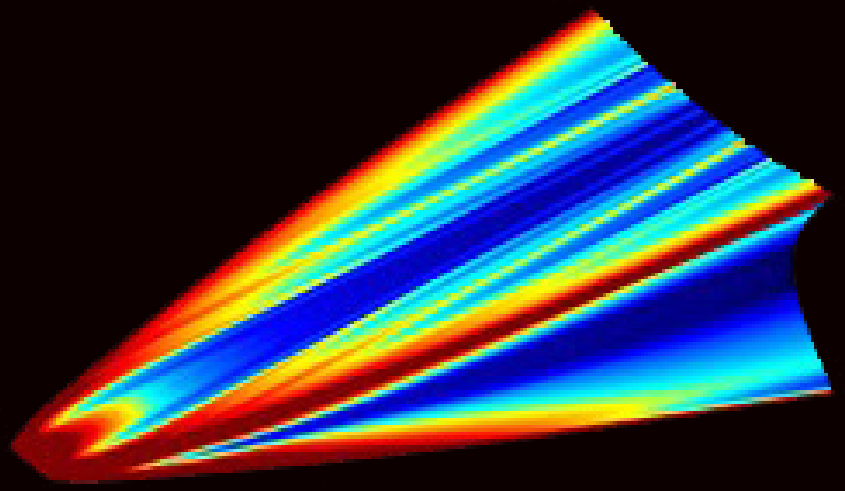
The user base and research applications for ARES have continued to expand since its introduction and release by AFRL. Initially inspired for use in materials science, ARES is being evaluated and adopted by research institutions across the nation and abroad. Through ARES, AFRL is pushing the envelope on research and scientific discovery.

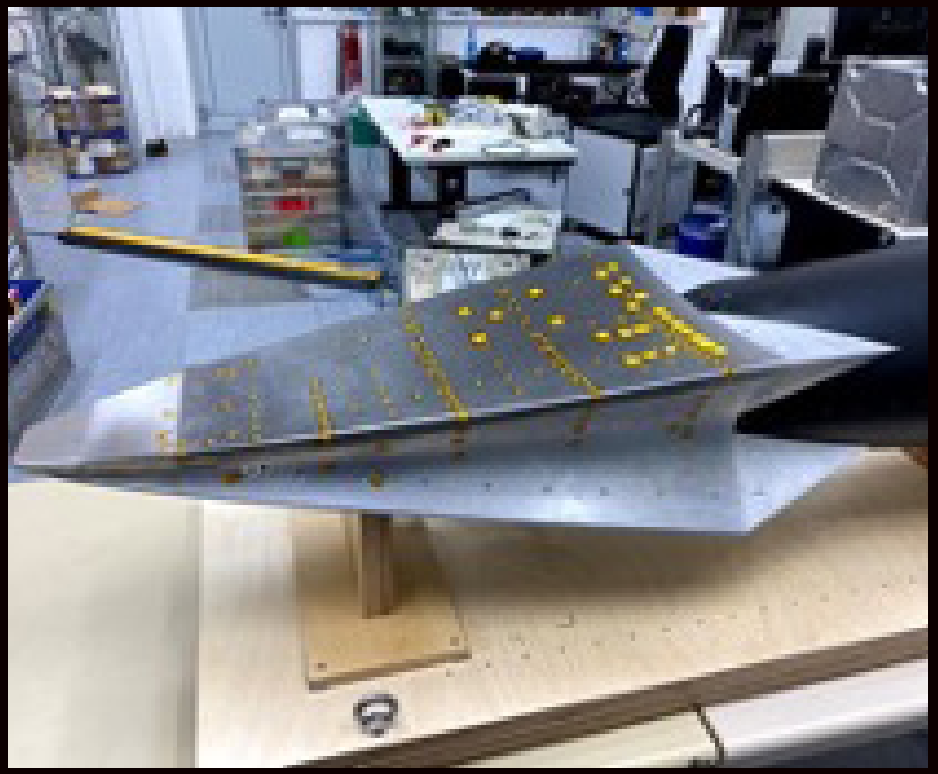
Hypersonic Computational Fluid Dynamics

Air Force Office of Scientific Research

As a key enabler to next-generation hypersonic vehicles, AFRL's Air Force Office of Scientific Research (AFOSR) funds academic research work in computational fluid dynamics, including that of international partners. Recently, direct numerical simulation of hypersonic fluid flow has reached new levels of sophistication, particularly thanks to AFOSR-funded work at multiple US universities, US government agencies, and international S&T agencies.

This research effort focuses on computation of hypersonic flow across complex wing body shapes. The goal is to understand the patterns of laminar boundary layer flow and turbulence effects, and thus to understand heat distribution patterns across the shape. While simulations, such as those shown in the left image, do not obviate the need for wind tunnel and flight experiments, they greatly accelerate design by streamlining the acquisition of knowledge. Simulations limit the number of prototypes, as in the right image, physical experiments, and risks that must be undertaken to validate the design of a successful hypersonic vehicle. AFOSR's Boundary Layer Transition (BOLT) hypersonics research and experimentation work has greatly expanded cross discipline research which leverages state-of-the-art ground test facilities and conducts flight experiments for a unique comparison across hypersonic science techniques. America's mastery of simulation leads to our rapid development of scientific knowledge and accelerates the fielding of critical technological capabilities.





Quantum Networking and Processing

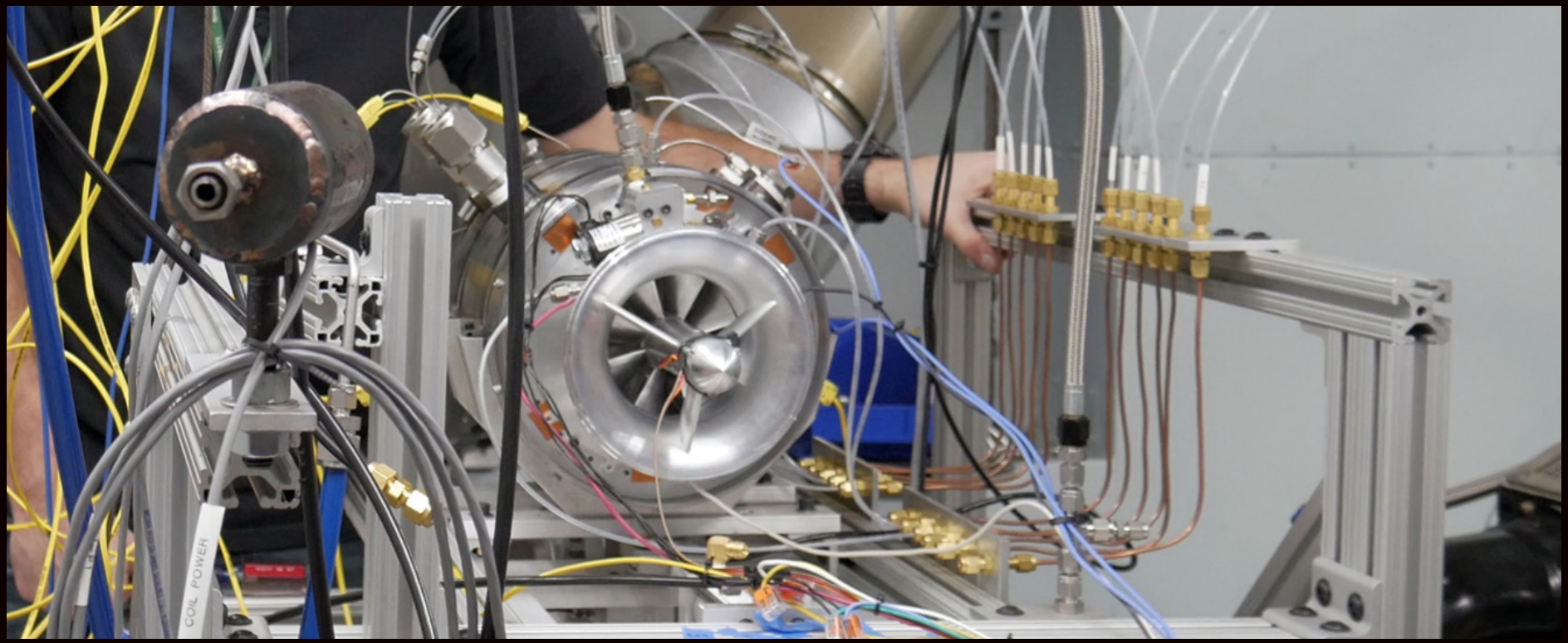
Information

The AFRL Information Directorate, as part of the Air Force Quantum Information Science Research Center, has established Quantum Computing and Distributed Quantum Networking Testbeds to enable in-house and industry partners to collaborate on experiments to develop quantum information capabilities, quantum algorithms, specialized quantum computing capabilities, and quantum networking and communications capabilities. These efforts will help drive forward the Department of the Air Force's understanding and mastery of quantum information science, identify applications for these novel computing modes, and secure tomorrow's information systems.

Responsive Open-Source Engine (ROSE)

Aerospace Systems

At the Aerospace Systems Directorate, Turbine Engine Division, AFRL recently designed, assembled, and in-house tested a small expendable turbine engine. ROSE, a project under the Emerging Engine System Program, is of a small thrust class suitable for small UAVs. The technology is available to manufacturers and developers of systems requiring small turbine propulsion. The developers worked closely with other AFRL organizations and the Air Force Institute of Technology. The program is an example of rapid development of new technologies through prototyping. By greatly reducing potential engine development costs for industry, new platform designs are made possible that might otherwise only be feasible for large production runs. The ROSE-derived design and cost savings encourages innovation in small platform developments for Air Force applications.



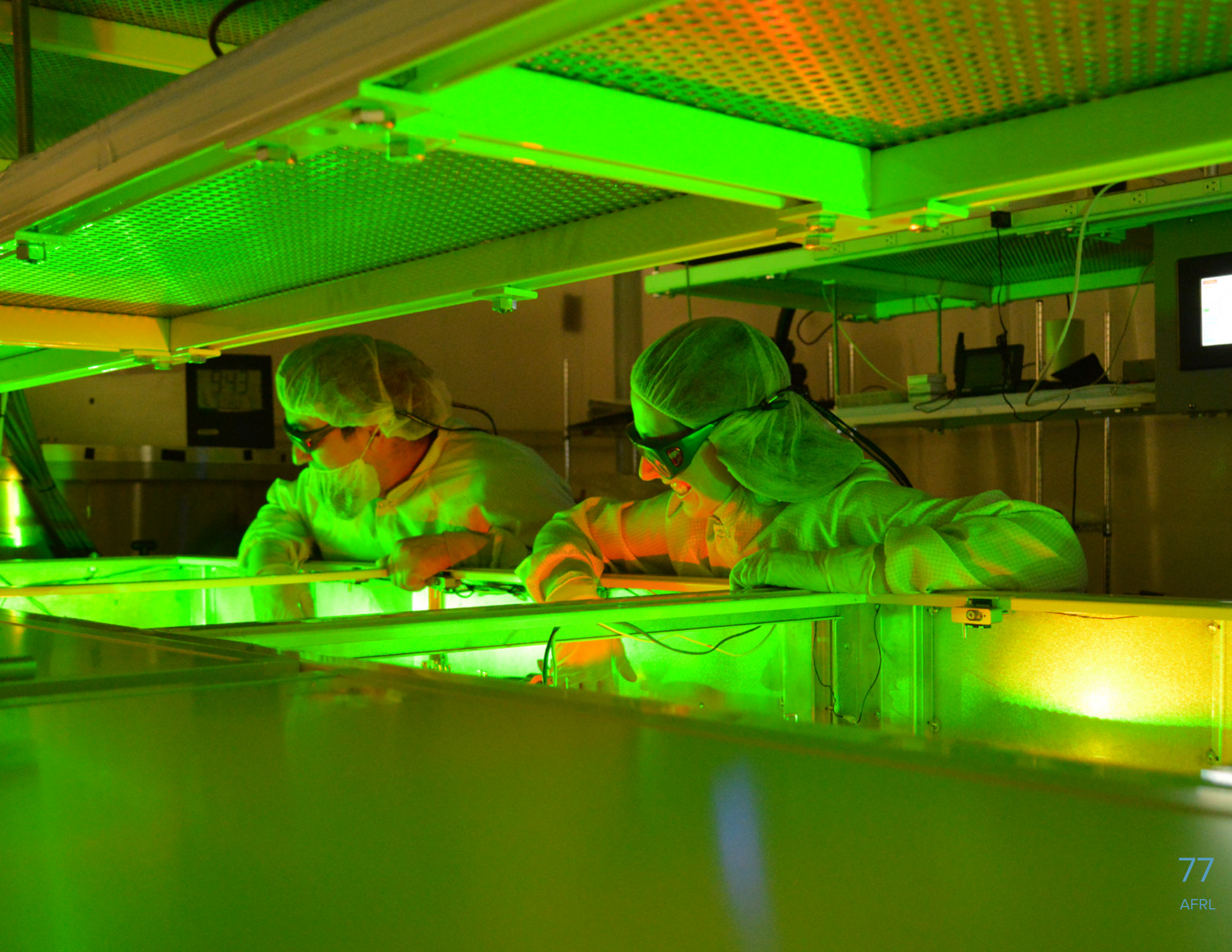
STEM Outreach

Air Force Research Lab

As the leader in Science and Technology, AFRL engages and fosters future talent to prepare for tomorrow's fight. Scientists and engineers from across AFRL work to inspire students of all ages, from elementary school through college, encouraging and enriching the learning of the next generation of scientific leaders. These young people represent the leaders and researchers who will find answers to the toughest questions of tomorrow's tomorrow. Over the course of Fiscal Year 2021, AFRL personnel volunteered over 6,000 hours to help teach and mentor approximately 40,000 K-12 students in all aspects of S&T. From chemistry, biology, and physics to math, computer science, medical science, and even quantum technologies, these sessions help ensure that students across the country are discovering the many fascinating questions awaiting answers and how they may contribute to answering them through scientific research like that being conducted at AFRL. Through its outreach work AFRL is working to build its future force.

STUDENTS CAN CONNECT WITH AFRL AT:
afresearchlab.com

6,291 Hours
40,314 K-12 Students



WAY FORWARD

In implementing the Department of the Air Force's S&T 2030 Strategy, AFRL has created a powerful vision of the AFRL of the future. With an operating model that adapts to changing needs within the DAF, the Lab is transforming the 2019 strategic vision into reality. Uniting the efforts of multiple working groups across AFRL, the Lab is accelerating S&T priorities for the Department and delivering the technological capabilities needed by the nation's warfighters. Extending to all aspects of the Lab's *Lead, Discover, Develop, and Deliver* functions, as well as the Commander's Transformational Imperatives, this drive and the tireless AFRL workforce will lead to AFRL's continued success as One Lab supporting Two Services.

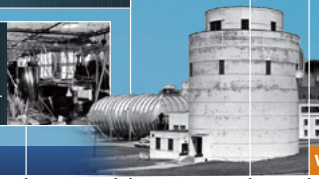
HERITAGE OF SCIENCE AND TECHNOLOGY FROM MCCOOK FIELD TO TODAY AND BEYOND

Since the dawn of flight, US aeronautical research has brought the military improved capabilities. Today's AFRL remembers these accomplishments with pride and is committed to delivering many more in the years to come.

1903
The Wright Brothers first flight.
December 17, 1903 (WSU)

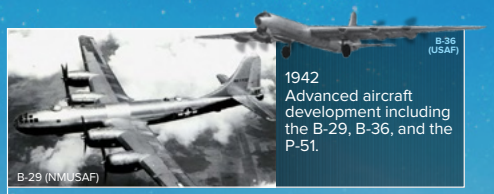
1927
Wright Field Opened.

1920
Aircraft construction shifts from wood and fabric to metal.



1935
Demonstration of first pressurized aircraft cabin.

1947
September 18 formation of United States Air Force.



1942
Advanced aircraft development including the B-29, B-36, and the P-51.

1952
Rocket testing moved from Dayton, OH to Edwards Air Force Base to accomodate the race to build intercontinental ballistic missiles. (NMUSAF)

1970
Simulation of a broad variety of mission environments were possible using the Dynamic Environment Simulator.

2005
AFRL's miniature munitions technology successfully demonstrated their increased accuracy, reducing the munitions lethal radius, and reduced collateral damage. (USAF)

2000
Mighty Sat II demonstrated a small satellite could provide swift demonstrations of high-payoff space system technologies. (AFRL)

2010 – 2030
The AFRL autonomy initiative centers on maturing the science needed to enable human-machine teaming in air missions.

2014
AFRL successfully combined multiple fiber laser beams into a single coherent high-power beam. (AFRL)

WWI | WWII | JET AGE | SPACE AGE | VIETNAM | FIRST GULF WAR

1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 2020

1917
McCook Field Groundbreaking. (NMUSAF)

1930 – 1940
Construction and initiation of vertical and 10-foot wind tunnel.

1926
July 2, 1926 formation of the United States Army Air Corps.

1944
The General Henry H. "Hap" Arnold commissioned a report, *Toward New Horizons*, surveying military R&D advances. Coordinated by Dr. Von Karman, the report was hugely influential and led to America's postwar airpower dominance. (USAF)

1947
First supersonic flight.

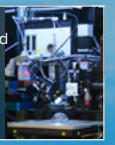
1950 – 1960
Rome Air Development Center led in the development of early warning and command and control equipment for continental air defense.

1942
The General Electric J35 was one of the first axial flow turbojet engines resulting in a more compact design. (AFRL)

1970 – 1980
The Air Force developed better command, control, communications, and intelligence systems. (AFRL)

1997
Formation of one Air Force Research Laboratory through the consolidations of four "Super Labs."

2017
AFRL demonstrated the ability to print solar cells on three-dimensional surfaces. (AFRL)



2013
May 1, the X-51 Waverider flew the longest duration scramjet flight to date and reached speeds over Mach 5. (AFRL)

READ MORE AT:
afresearchlab.com


602
602

afresearchlab.com