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INTRODUCTION

Mr. Chairman, Members of the Subcommittee and Staff, I am pleased to have the opportunity to provide testimony on the Fiscal Year 2017 Air Force Science and Technology (S&T) Program and our efforts to innovatively and affordably respond to warfighter's needs now while simultaneously creating the force of the future.

As you heard the Secretary of Defense state recently, the Fiscal Year 2017 President's Budget takes the "long view" required to sustain our lead in full-spectrum warfighting. During the Acquisition Reform hearing in early January, we shared thoughts with the full Committee on the changing character of war and the inevitability of increasingly rapid change. On one side, the Department is thinking about the long-term capabilities necessary to fight in 10, 20 or 30 years down the road. On the other side, we've recognized that the relentless pace of change increases complexity and decreases predictability in warfare. As stated in the Air Force *Future Operating Concept*, "no technology or technique will eliminate the metaphorical fog and friction of warfare, and no military advantage will go unchallenged by adversaries seeking to achieve their objectives and deny us ours."

Given this environment of rapid change, how do we as an Air Force—and as a Department as a whole—ensure we have the capabilities we need to dominate the current fight, prepare for the future fight, and/or deter it from happening at all? We believe the answer is to bring a new level of agility and innovation into our capability development processes, workforce and infrastructure. As highlighted in the Air Force Strategy, *America's Air Force: A Call to the Future*, strategic agility allows us to rapidly adjust to evolving threat environments faster than our adversaries and can help us counter uncertainty. The Air Force's efforts in this area, many of which are described in this statement, support the building blocks of the Department's Third Offset Strategy and our Fiscal Year 2017 Air Force S&T Program has alignment to the Long Range Research and Development

Planning Program initiatives. From an acquisition perspective, our Air Force efforts also incorporate and support the Better Buying Power (BBP) 3.0 initiatives under the leadership of Mr. Frank Kendall, Under Secretary of Defense for Acquisition, Technology and Logistics (AT&L). The BBP 3.0 initiatives are endeavoring to strengthen our ability to innovate, achieve technical excellence, and field dominant military capabilities.

The following statement provides an overview of the Air Force's move toward strategic agility in capability development through reinvigorating development planning, maximizing the impact of our robust S&T program (game-changing, enabling, relevant, and rapid technologies), increasing efforts in experimentation and prototyping, and leveraging the contributions of our entire world class workforce and infrastructure.

AIR FORCE FISCAL YEAR 2017 S&T PROGRAM AND ASSOCIATED EFFORTS

As our budget request highlights, Air Force senior leaders are committed to science and technology and embracing new paradigms in capability development. The Air Force Fiscal Year 2017 President's Budget request for S&T is approximately $2.5 billion. This is an increase of $108 million or a 4.5% increase from the Fiscal Year 2016 President's Budget request. We have emphasized research in hypersonic and low cost cruise missile technologies to provide the capability to counter adversary anti-access and area-denial (A2/AD) in support of the Long Range Research and Development Planning Program; advanced air combat missiles; and research in technologies to provide robust position, navigation and timing (PNT) capabilities. The Air Force Fiscal Year 2017 President's Budget request also includes funding in Budget Activity 4 (Advanced Component Development and Prototypes) and in Budget Activity 6 (RDT&E Management Support) to support our prototyping, experimentation, and modeling and simulation efforts. Approximately $62 million for prototyping and experimentation funds the experimentation campaigns chartered by Air Force senior leaders and approximately $285 million funds the Adaptive Engine Transition

Program (AETP). More information on these efforts is provided later in this statement. Approximately $13 million of integrated modeling and simulation funding will be used to build and maintain the tools and virtual environments necessary to conduct development planning, prototyping, and experimentation.

AGILITY IN CAPABILITY DEVELOPMENT

To capitalize on the increasingly dynamic environment, the Air Force is aggressively pursuing a path toward *strategic agility*. At its heart, the term *agility* means the ability to act appropriately within a changing context and captures the attributes of *flexibility*, *adaptability*, and *responsiveness*. Flexibility is the hallmark of airpower, and the adaptability of our Airmen, organizations, operational concepts, and weapon systems has long underwritten that flexibility. We now look to our Airmen to foster a culture which values anticipation over reaction and shaping over responding. Achieving greater agility in how we organize, train, equip, and employ our Air Force provides a *strategic* advantage over potential adversaries. The Air Force is not forging this paradigm shift in capability development simply for our own sake, but for the sake of the joint fight and the Nation.

We're also not starting this endeavor from scratch. Historically, we've used development planning to drive innovation and plan our future. Our reinvigoration of development planning at the Air Force enterprise level gets us back to our roots to formulate truly innovative strategic choices and leverage the attributes of agility in our capability development. Development planning enables us to understand and synthesize future warfighting needs and reconcile those with available and potential capabilities, concepts, and emerging technologies and will be a key process to support Air Force strategic decisions. Key development planning functions to achieve this understanding include: systems engineering to formulate and evaluate viable concepts; operational trade space analysis and definition; technology shortfall identification; S&T needs and gap analysis; and requirements refinement. In conjunction with development planning, the Air Force is conducting experimentation and prototyping activities which bring together operators, technologists, requirements, and acquisition professionals to explore the full range of multi-domain innovative materiel and non-materiel solution options. These activities provide an environment where our Airmen can take smart risks when exploring innovative ideas.

The Air Force is using an Enterprise Capability Collaboration Team (ECCT) approach to facilitate development planning for our highest-priority mission areas. ECCTs have the freedom to explore concepts with a direct path to senior leadership for quicker decisions on courses of action to increase agility across the enterprise. The ECCTs are leveraging knowledge and expertise residing in the Air Force operational community, acquisition enterprise, the DoD laboratory enterprise, Federally Funded Research and Development Centers (FFRDCs), academia, and industry, as appropriate.

CONTRIBUTION OF AIR FORCE S&T IN AGILE CAPABILITY DEVELOPMENT

The Air Force S&T Program plays an integral role in developing technologies to provide options for our forces of tomorrow and ensuring needed technologies get into the hands of our warfighters today. The Air Force emphasized the role of S&T by dedicating an annex in the Strategic Master Plan which outlines a strategic approach to S&T and the supporting elements necessary to bring forth the next generation of capabilities.

Game-Changing (Revolutionary) Technologies

As outlined in *America's Air Force: A Call to the Future*, we are focusing on several game-changing technologies that can amplify many of the enduring attributes of airpower—speed, range, flexibility, and precision. These game-changing technologies are: autonomous systems, unmanned systems, hypersonics, directed energy, and nanotechnology. The Air Force's S&T efforts in autonomous systems and unmanned systems provide key support to the realization of the five enablers of the Department's Third Offset Strategy.

Autonomous Systems

Autonomy has the potential to enhance Air Force readiness for increasingly complex, future operating environments. Autonomous systems can provide new approaches to airpower by potentially reducing unnecessary manning costs and time required for critical operations while increasing the range of operations and levels of reliability, persistence and efficiency. While autonomous systems can extend human reach by providing potentially unlimited persistent capabilities without degradation due to fatigue or lack of attention, such increases in machine autonomy requires humans and automated systems to work as a team, with some level of decision-making delegated to the machine counterpart.

Our research seeks to find the right balance of human and machine capability to meet Air Force challenges in the future. To achieve optimal human-machine teaming, the Air Force is developing technologies to enable Airmen and machines to work together, with each understanding mission context, sharing understanding and situation awareness, and adapting to the needs and capabilities of the other. Additional research is focused on understanding human cognition and decision-making and applying these concepts to machine learning. These efforts are developing efficient interfaces for an operator to supervise multiple unmanned aerial system (UAS) platforms and providing cyber operators and intelligence, surveillance, and reconnaissance (ISR) analysts with tools to assist in identifying and tracking targets of interest.

To achieve human-machine cooperation in a complex, contested environment, the Air Force is focused on increasing machine intelligence. Cooperative, distributed system technologies will enable machines to synchronize activity and information. Systems that coordinate location, status, mission intent, and intelligence and surveillance data can provide redundancy, increased coverage, decreased costs and/or increased capability. Air Force S&T efforts are focused on the coordination and integration of disparate sensor systems across multiple aircraft as well as developing munition sensors and guidance systems that will increase operator trust, validation, and flexibility while capitalizing on the growing ability of munitions to autonomously search a region of interest, provide additional situational awareness, plan optimum flight paths, de-conflict trajectories, optimize weapon-to-target orientation, reduce operator workload, and cooperate to achieve optimum effects. To help ensure safe operations of autonomous systems, the Air Force is researching the architectures and mechanisms to prevent cyber intrusions, and as importantly, developing capability in the system to detect anomalies and validate data. We have initiated research to develop and test techniques to verify the decision-making and logic of the system and validate the system's ability to operate safely and effectively in unanticipated and dynamic environments.

Unmanned Systems

With the advent of unmanned warfighting capability, there is a new path for disaggregation. By removing the operator from the aircraft, unmanned platforms can be made less complex and much smaller. This allows the complexity of the air mission system to be increased, as needed, through composition of multiple, simpler platforms. Mission packages may be composed of specialized, unmanned platforms performing each of the needed functions singly such as global communication, precision navigation, target identification, and weapon delivery. Disaggregated unmanned air systems present a new dimension for achieving the operational agility envisioned in the Air Force *Future Operating Concept* and the Department's Third Offset Strategy.

There are expansive technology requirements to field a disaggregated unmanned system. These systems will have a critical dependence on secure tactical communication to share services across the mission package. They will require a robust combination of onboard autonomy and distributed command and control. To fit high performance functionality on small platforms requires advanced structural concepts, flexible electronics, and advanced onboard power sources. Other needs are new classes of distributed, collaborative sensors and onboard data fusion. This class of vehicles will also need to navigate safely in airspace as well as launch, refuel, and recover in unique ways.

The Air Force S&T Program is addressing many of these issues. For example, we have multiple efforts to enhance propulsion and power performance for smaller air vehicles and our robust portfolio of autonomy investments discussed earlier in this statement will allow for critical onboard decision-making and enhanced human-machine interfaces. Air Force S&T efforts in this area are focusing on advancing and enhancing rapid and agile manufacturing techniques for these systems. In addition, the Air Force Research Laboratory has demonstrated and fielded multiple approaches to collision avoidance to allow for safe airspace integration.

This class of platforms also presents an ideal context for advancing our capability for rapid, agile development and fielding. One of these efforts, Low Cost Attritable Aircraft Technology (LCAAT), is discussed later in this statement along with other rapid transition and fielding activities. Development can accelerate by establishing new certification standards for these low-cost, limited life airframes. A commitment to open architectures and interface specifications allows for upgradable modularity. Integration of design and manufacturing, coupled with automated and additive construction, opens the door to purpose-built platforms. This unique opportunity for frequent, simplified technology refresh will keep these disaggregated unmanned systems ever-relevant and cost effective.

Hypersonics

Hypersonics are one of the game-changers that provide high-speed options for engaging time sensitive targets, while improving the survivability of Air Force systems. The Air Force is developing technologies for a High Speed Strike Weapon (HSSW) to enable a responsive, long-range strike capability. These weapons can be employed from fighters and bombers and fly at hypersonic speeds to their intended target on the ground.

The Air Force continues to partner with the Defense Advanced Research Project Agency (DARPA) on two flight demonstration programs for HSSW technologies: Hypersonic Air-breathing Weapon Concept (HAWC) and Tactical Boost Glide (TBG). These programs intend to address three technology challenge areas: air vehicle feasibility, effectiveness and affordability. The HAWC program aims to develop and demonstrate critical technologies and attributes of an effective and affordable hypersonic cruise missile. The TBG program aims to develop and demonstrate technologies to enable future air-launched, tactical-range hypersonic boost glide systems.

The HSSW Technology Maturation (Tech Mat) effort is developing technologies to complement the DARPA-Air Force HSSW demonstrations and to expand the technology trade space in hypersonics. HSSW Tech Mat focuses on longer term enabling and enhancing technologies. Some of these include: ordnance; advanced materials and manufacturing; guidance, navigation, and control; and solid rocket motor technologies.

Directed Energy

The Air Force has invested in directed energy (DE) including high power microwave (HPM) and high energy laser (HEL) technologies to the point that we are now positioned to provide Airmen distinctive and revolutionary capabilities for several Air Force and joint mission areas. With a uniquely focused high power DE S&T organization with a wide range of modern, dedicated facilities and an excellent scientist and engineering (S&E) workforce, including a large number of young military officers, the Air Force is in a leading position in this game-changing area.

We recently initiated S&T efforts to implement DE on small and rapidly maneuvering platforms where size, weight and power scaling are major challenges. This effort, when accomplished, will provide a force multiplier by placing both kinetic and non-kinetic weapons capabilities on our current platforms.

Lower power laser technologies are rapidly evolving for infrared seeker jamming, improved ISR and target identification, and secure communications in congested and jammed spectrum environments. To make HEL weapon systems useful to the warfighter, our S&T program invests in research for laser sources that include narrow line width fiber laser amplifiers that when combined in large numbers produce weapons class lasers. To complement the laser source development, the Air Force has parallel research in beam control component and system-level technologies; atmospheric compensation, acquisition, pointing, tracking, laser effects; and physics-based end-to-end modeling and simulation. All of these technologies are maturing to a point where the Air Force S&T Program can now address the highly turbulent environment for correcting aero effects on the laser beam from an aircraft. This will be demonstrated by integrating a moderate power laser system into a standard fuel pod for aircraft self-protection applications.

The High Energy Laser Joint Technology Office (HEL JTO) supports all of the Services under Office of the Secretary of Defense (OSD) leadership by translating requirements into technology. The HEL JTO is a key enabler to the HEL community at the component level for laser sources, beam control, lethality, and modeling and simulation. Several advances in the development of high power laser devices like the 100 kilowatt, laboratory-scale Joint High Power Solid State Laser and the Robust Electric Laser Initiative would not have occurred without HEL JTO leadership, joint service collaboration, and adequate funding. The HEL JTO is also developing the Advanced Beam Control for Locating and Engagement program that will advance pointing and tracking through the use of improved sensors and adaptive optics. The Services are leveraging these components and designs for inclusion in future weapon systems.

Air Force HPM S&T will complement kinetic weapons by engaging multiple soft targets and neutralizing communication systems, computers, command and control nodes, and other electronics, with low collateral damage for counter A2/AD in future combat situations. Using the results from the highly successful Counter-Electronics High Power Microwave Advanced Missile Project (CHAMP) Joint Capabilities Technology Demonstration, there is research investigating size, weight and power updates for a more effective, more capable weapon delivering a broader spectrum of microwave effects on a smaller platform. In addition, the Air Force is refurbishing the two remaining CHAMP platforms and investigating options for them to be used by the warfighter to address the vehicle survivability, environment suitability, range, reliability, and maintainability issues highlighted by the Operational Utility Assessment.

Nanotechnology

Emerging research and developments at nanometer dimensions—below 100 nanometers—promise revolutionary technological changes for a wide range of Air Force and DoD applications and platforms by delivering materials, coatings, devices and sensors with new and novel performance. Nanotechnologies to be incorporated within the Air Force platforms are directly relevant to the Air Force technology areas of aerodynamics, mobility, stealth, sensing, power generation and management, smart structures and materials, resilience and robustness, and augmented human performance. In addition, Air Force S&T efforts are investigating how nanotechnologies will impact battlespace systems concerned with information and signal processing, autonomy and intelligence. Our Air Force S&T investment in this game-changing technology will also enable the development of novel materials providing the basis for the design and development of new properties and structures resulting in increased performance, reduced cost of maintenance, and enhanced functionality.

The Air Force is also leveraging advances in nanoscience to enable game-changing computing technologies. For example, our investment in this area includes large-scale symbolic inference models and subsequent computing architecture implementations for affordable, agile, autonomous, and trusted systems capable of ingesting and processing big data to support decision makers. Multifunctional nanoelectronics and nanomaterials involving hybrid and three-dimensional (3D) stacking will provide a 100 times increase in computing density, and enable human-level computing capacity in embedded systems. Ensuring a U.S. industrial base for nanofabrication capabilities will be critical to competitively enabling this functionality in domestic systems. Towards this end, Air Force Research Laboratory researchers are working closely with the nanofabrication facility at the State University of New York Polytechnic Institute to collaborate and exploit advancements in nanoelectronic design and manufacturing, thus shortening the time from concept to fielding to the warfighter.

Enabling Technologies

In addition to these game-changing technologies, the Air Force S&T Program also invests in many enabling technologies to facilitate major advances and ensure maximum effectiveness in the near-, mid-, and far term.

Basic Research

Basic research embraces the challenge set forth by Air Force senior leadership by driving game-changing innovation to achieve the art-of-the-possible. The development of revolutionary capabilities requires the careful investment in foundational science to generate new knowledge.

Air Force basic research sits at the center of an innovation network that tracks the best S&T with our partners in the Army, Navy, Defense Threat Reduction Agency, and DARPA while monitoring the investments and breakthroughs of the National Science Foundation, NASA, the Department of Energy, and National Institute of Standards and Technology. Furthermore, through open, publishable research that cuts across multiple scientific disciplines Air Force S&Es attend to and collaborate with the best universities and research centers from around the world. Our scientists and engineers seek out the potential military utility of new ideas and concepts to transition game-changing S&T to the Air Force and our partners. The Air Force S&T Program integrates these developments and provides the support to inject scientific results and innovative breakthroughs into the research and acquisition community.

Game-changing capabilities begin with foundational, cross-cutting and revolutionary basic research. For instance, Air Force researchers have performed the first fully resolved direct numerical simulations of the turbulent boundary layers of interest to hypersonic flight. This fundamental research is leading the way to determining the 3D unsteady separation of the flow on control surfaces. The basic research modeling and simulation work is being applied to high fidelity wind tunnel testing and flight data simulation, with additional application to thermally-induced structural distortions on hypersonic weapons.

Live, Virtual, and Constructive (LVC)

Our national security challenges make it imperative that our forces be prepared to meet the challenges of the future battlespace through realistic training environments. The Air Force strategy, *America's Air Force: A Call to the Future*, describes Live, Virtual, and Constructive (LVC) as "one of the more promising paths to agility in operational training and readiness." As such, our Air Force S&T Program is continuing to develop and demonstrate technologies for LVC operations to maintain combat readiness.

The need for LVC is highlighted as training costs are increasing and threat environments become highly complex. In particular, realistic training for A2/AD environments is not available. Past demonstrations of Air Force S&T LVC capability for tactical air have integrated an F-16 networked simulation environment (a virtual simulator) to simultaneously interoperate with a mix of live F-16 aircraft, other virtual simulations (including the immersive environment known as the Joint Terminal Attack Controller Training and Rehearsal System), and high-fidelity, computer-generated constructive players. This mix of players enabled the real time and realistic portrayal and interaction of other strike package assets and aggressor aircraft with a level of complexity that could not be achieved if limited to live assets, given the expense and resource availability to support the scenarios.

Although the example just discussed is for tactical air, LVC can apply to other operational domains, such as special operations; cyber; ISR; and command and control (C2). A recent example of a successful LVC demonstration is the integration of live Joint Terminal Attack Controllers (JTACs) with live A-10 aircraft in a training exercise. The JTACs were operating within the Joint Theater Attack Controller Training and Rehearsal System and were coordinating air strikes with the A-10 aircraft. For the Air Force medical community, LVC is envisioned to support training for expeditionary medicine, enroute medical care, and schoolhouse medical training. The Air Force Research Laboratory is teaming with the U.S. Air Force School of Aerospace Medicine to review these areas of LVC application.

In Fiscal Year 2017, the Secure LVC Advanced Training Environment (SLATE) effort is planned to continue LVC hardware and software development, 5th generation waveform maturation and Operational Flight Plan (OFP) modification. These S&T efforts will focus on upgrades to range infrastructure and integration of LVC pod/internal form factor for the F-35 which will include a new datalink and Multiple Independent Levels of Security (MILS) encryptor and processors.

Position, Navigation, and Timing

The Air Force is emphasizing S&T efforts in PNT to improve the robustness of military Global Positioning System (GPS) receivers and also developing several non-GPS based alternative capabilities including exploitation of other satellite navigation constellations, use of new signals of opportunity, and incorporation of additional sensors such as star trackers and terrain viewing optical systems. These receivers provide new navigation options with different accuracy depending on available sensors and computational power.

We are collaborating with DARPA, the Army, and the Navy on the development of future adaptable military navigation systems. In this endeavor, we are promoting technology trends toward more open architectures and software defined radios for navigation systems to address future spiral enhancements and control cost growth of embedded GPS-inertial avionics. We are also partnered with DARPA on inertial and clock size, weight, power, and cost (SWaP-C) advances via a variety of technological approaches and in starting a new very low frequency (VLF) terrestrial beacon based navigation and timing research effort. We have also conducted multiple GPS-denied vision-aided inertial flight experiments that demonstrate a small percent of distance traveled error accumulation in position accuracy.

Manufacturing Technologies

The Air Force's Manufacturing Technology program has focused on promoting technologies for an agile, next generation manufacturing industrial base with strategic benefits in efficiency, affordability, and capabilities in Air Force warfighting products. The program strategically aligns key agile manufacturing objectives including: 1) moving manufacturing considerations earlier in the design cycle to reduce acquisition cost and risk; 2) enabling seamless lifecycle management through an integrated digital thread to document and improve process control, optimization, and manufacturing agility; 3) integrating the industrial base enterprise to predict, identify, and react to supply chain issues; and 4) creating the factory of the future with flexible, smart machine cells and assembly processes that are efficient even at low volume production. Several agile manufacturing initiatives are now underway. The Agile Manufacturing for ISR (AMISR) AgilePod effort is focused on developing and implementing advanced manufacturing techniques to enable affordable, low volume production of open architecture multi-sensor ISR pods. The Air Force Manufacturing

Technology Program is also key to the LCAAT effort to develop and demonstrate a capable, attritable aircraft for less than $3 million without mission systems. More information on this effort is provided later in the statement.

The Air Force is continuing support to the Manufacturing Institutes as part of the National Network for Manufacturing Innovation. The Air Force Research Laboratory participates on Technical Advisory Boards and Government Advisory Boards and provides subject matter experts (SMEs) for source selection and project execution. The two newest institutes are the American Institute for Manufacturing-Integrated Photonics **(**AIM-IP) and Next Flex for flexible hybrid electronics. AIM-IP was established in August 2015 and is focused on developing novel manufacturing processes for integrated photonic devices. Air Force applications include but aren't limited to lasers, detectors, waveguides/passive structures, modulators, electronic controls and optical interconnects. NextFlex was established in September 2015 and is focused on developing highly tailorable devices on flexible and stretchable substrates. Air Force applications include integration of flexible components such as circuits, communications, sensors and power with more sophisticated Silicon-based processors. Both institutes utilize a "shared" leadership model with an Air Force Research Laboratory Chief Technology Officer (CTO) responsible for the technical vision of the institute.

Material Technologies (Sustainment)

At all stages of defense planning sustaining the force remains a priority. The average age of our air and space forces is at a historic high and will continue to increase. For this reason the acquisition life cycle of our defense systems needs to ensure planning for sustainment early in the cycle. For fielded systems the need to improve sustainability and increase life cycles is also imperative. This is an area where we can and must be more innovative and less risk averse in discovering and demonstrating additional methods to sustain our existing assets.

Air Force S&T is directly contributing to this fight. We are committed to developing new technologies to sustain our current systems as evidenced by our work developing new materials, manufacturing processes and Non-Destructive Inspection (NDI) techniques, and improving maintenance and repair diagnostics, and analysis tools for life prediction and extension, fleet management, and decision-making. For example, data mapping analysis technology will be demonstrated on the B-1B Lancer to incorporate NDI and additional maintenance and repair data. Additionally, the C-5 Galaxy will be our test bed for an environmental data/dwell time model that will more accurately estimate the state and location of an aircraft's corrosion.

Relevant Technologies

Cyber

The execution of Air Force core missions to deliver airpower relies on the ability to effectively operate in cyberspace. Operations in cyberspace can magnify military effects by increasing the efficiency and effectiveness of air and space operations across all domains. However, the cyberspace domain is becoming increasingly contested and denied and the Air Force faces risks from malicious insiders, insecure supply chains, and increasingly sophisticated adversaries.

Air Force S&T efforts in mission assurance are pursuing survivability and freedom of action in contested and denied environments through enhanced cyber situational awareness for air, space, and cyber commanders. Current foundational research focuses on detection and protection of cyber penetration into Air Force mission systems. This work concentrates on stopping attacks before systems are fully compromised. Going beyond the current strategies of firewalls and virus/malware detection, the technologies being developed will understand attacks, discover persistent threats, and use a framework to allow resources to collaborate on a defense. This will allow the Air Force to maintain operations in a contested cyber environment. The research provides an array of foundational technology options to Air Force cyber needs and requirements.

We are also conducting research in agility and survivability to develop technologies that disrupt adversaries' cyber "kill chain," along with their planning and decision-making processes, and hardening our cyber elements to improve the ability to fight through, survive, and rapidly recover from attacks. Air Force S&T efforts are improving our agility within cyberspace by investigating techniques called moving target defenses and by providing a C2 structure to plan, assess, and execute a coordinated defense for our Air Force networks. Our efforts are developing visualization technologies that will enable a global common operational picture of complex cyber capabilities that can be readily manipulated to support Air Force mission-essential functions. Other cyber efforts seek to identify critical human skills and abilities for cyber warriors and develop a realistic distributed network training environment.

The Air Force is developing secure foundations of computing to provide operator trust in Air Force weapon systems, including a mix of embedded systems, customized and militarized commercial systems, commercial-off-the-shelf (COTS) equipment, and unverified hardware and software developed outside the U.S. To counter the lack of hardware-based cyber security features which allow exploitation of software vulnerabilities, Air Force S&T is developing and testing a secure central processing unit (SCPU). The resulting government-owned intellectual property could be used to secure future embedded systems such as remotely piloted vehicles or other mission critical or autonomous systems.

Additionally, research into formal verification and validation of complex, large scale, interdependent systems, as well as vulnerability analysis, automated reverse engineering, and real-time forensics tools will enable designers to quantify the level of trust in various components of the infrastructure and to understand the risk these components pose to the execution of critical mission functions.

Assured Communications

The Air Force S&T Program is investing in many areas to assure communications across our domains. We are developing technologies to counter global threats to mission performance (spectrum congestion and jamming), increase capacity over longer range air-to-air with military-grade security, and maintain or increase available bandwidth through dynamic spectrum access to new portions of the radio frequency (RF) spectrum, alleviating pressure on DoD spectrum allocations. Future access to the new spectrum will increase DoD communications architecture capacity and affordability, by requiring fewer expensive, high capacity gateways. Additional bandwidth will also allow improved anti-jam communications performance and higher frequency communications, which will reduce scintillation losses for nuclear command and control. The performance enhancements will directly improve the ability of remotely piloted vehicles to transmit images and data (ISR), improve C2 assurance, and increase communications support to Air Force core missions.

We are building upon ongoing research in several technical areas, such as V/W band experiments for high capacity satellite communications, non-proprietary multi-gigabit data link, Joint Warfighting Integrated Network operations, and advanced anti-jam waveform development for next generation software defined radio frequency systems. We have initiated a new effort to develop the specification and reference architecture for a revolutionary new networked directional data link for airborne systems. These new inexpensive and interoperable radios/waveforms will be able to survive and operate in future contested environments. Our approaches will leverage cost effective commercial best practices tailored to rapidly deliver revolutionary new mission capability. For example, developing a Waveform Development Language baseline will encourage competition, increase interoperability, enable dynamic on-demand assured connectivity, and drive down the cost of developing/testing waveforms. It will steer away from proprietary and single-use solutions and rather focus on developing technology that can be built upon and that will serve multiple purposes.

The Air Force is the primary Service responsible for the modernization, sustainment and the technological advancement of nuclear command, control and communications (NC3) systems since we own approximately 75 percent of the Nation's NC3 systems. The Air Force S&T Program is investing in the Assured Communication for Nuclear Command and Control (ACNC2) effort to address key aspects of technological advancement with the goal of achieving a significant return on investment for the Air Force's key stakeholders. The ACNC2 effort will provide the warfighter with a full understanding of the anti-scintillation characteristics of the V/W bands for survivable beyond-line-of-sight (BLOS) communications; adaptive digital signal processing technologies for higher performance in existing and next-generation systems; survivable multiple levels of security and information management solutions for the Air Force nuclear enterprise; and an unprecedented capability to perform modeling, simulation and emulation for end-to-end NC3 operational assessment.

Electronic Warfare

Electronic warfare, conducted by manipulating the electromagnetic spectrum, can negate the integrated air defenses of our adversary and allow us to conduct missions in an A2/AD environment. This requires ways to defeat new sensors operating across the electromagnetic spectrum, with more elaborate detection methods, and greater computational, networking and cyber capabilities of adversaries. These capabilities defeat the detection and engagement from threat systems using RF, Electro-Optical (EO), Infrared (IR), and thermal technology.

Air Force S&T efforts in this area have reduced size, weight, and power (SWaP) and improved the algorithms in the Visible Missile Warning Sensor (VMWS) development. The sensor performed very well at live-fire tests in August 2015 and the requirements and design for a

Technology Readiness Level (TRL) 6 sensor are underway. The Air Force Research Laboratory also incorporated improvements to the Proactive infrared countermeasures (IRCM) testbed and demonstrated multi-spectral detection and identification of targets at range. Tests will continue to refine the algorithms and the capability will be incorporated into a Proactive Advanced Technology Demonstration (ATD) slated to begin in Fiscal Year 2017.

Long Distance Sensing

While over the past decade we have been able to conduct airborne ISR operations outside of the lethal range of air defense systems, we do not expect this to be the case in the future. Today's foreign Integrated Air Defense Systems (IADS) have increased lethality and significantly improved engagement capabilities that will force ISR aircraft to fly at longer stand-off distances. With distance limiting the ability to accurately detect, identify, and geo-locate targets the effectiveness of current precision weapons will be reduced. The Air Force S&T program is investing in improving our long standoff sensing capability and adequately addressing the challenges of extended range ISR collection.

The Identification at Range Integrated Sensor (IRIS) program has made excellent progress over the last year and is on track for long range imaging demonstrations in the Fiscal Year 2016 and 2017 time frame. IRIS is a synthetic aperture Laser Radar (LADAR) program that seeks to provide target identification through geometric imaging at ranges and resolutions exceeding the geometric imaging limits of conventional apertures. Significant progress has been made in the transceiver development, image formation algorithms, and modeling and simulation.

Hydrocarbon Boost

The Hydrocarbon Boost Demonstration (HCB) effort is expected to result in the most advanced liquid rocket engine technologies in the world. The engine cycle used is 30 percent more efficient than that used in all previous and current U.S. hydrocarbon fueled rocket engines.

Last year, the program tested a sub-scale pre-burner. Numerous lessons learned at this scale at a fraction of the cost were applied to enable successful completion of the preliminary design of the full-scale pre-burner that will be used in the final demonstration. In addition to being a part of the hydrocarbon boost final demonstration, the Air Force-developed full-scale preburner will be tested at the NASA Stennis Space Center facilities. Full-scale preburner testing will enable the testing of the full-scale thrust chamber combustion stability rig. This testing should occur in 2017 and will provide additional data for the program. The full-scale pre-burner critical design review is currently scheduled to be completed in May 2016. We completed preliminary design of the turbopump assembly, the most difficult component, and will conduct the critical design review in June 2016. The HCB demonstration is also validating new physics-based modeling, simulation, and analysis tools we developed in an earlier program and is already having an impact on Industry. The HCB demonstration is part of the Rocket Propulsion 21 program, a coordinated program chaired by OSD and NASA with the three Services and industry aimed at improving rocket propulsion technology for the nation.

Munitions

The Air Force is investigating new missile technologies to support advanced capabilities for future platforms in the 2030 timeframe. One of the new weapon concepts being explored is the Small Advanced Capabilities Missile (SACM). The SACM will be affordable and provide high loadouts compared to current air-to-air missiles. Another of these new concepts is the Miniature Self-Defense Munition (MSDM). The MSDM would enhance future platforms self-defense capability, without impacting the primary weapon payload.

Space Situational Awareness (SSA)

To help build a holistic national SSA capability, the Air Force's S&T investment is designed to leverage our in-house expertise to innovate in areas with short-, mid- and long-term impact that are not already being addressed by others. As part of our long history of proving new technologies in relevant environments, the Automated Navigation and Guidance Experiment for Local Space (ANGELS) program examines techniques for providing a clearer picture of the environment around our vital space assets through safe, automated spacecraft operations above Geosynchronous Earth Orbit (GEO). Equipped with significant detection, tracking and characterization technology, ANGELS launched in 2014, successfully maneuvered around its booster's upper stage and explored increased levels of automation in mission planning and execution, enabling more timely and complex operations with a reduced footprint.

We also have investments in S&T for ground-based optical SSA. The Air Force currently has two unique 3.5 meter class telescopes that it uses both to conduct research in characterizing space objects in low earth orbits up to GEO orbits and to support various customers in providing near real-time data on such satellites. One of the systems is located at the Starfire Optical Range (SOR) on Kirtland Air Force Base, New Mexico and the other is located at the Maui Space Surveillance System (MSSS) on the island of Maui, Hawaii. These sites are complementary SSA sites: technically, geographically, situated in different atmospheric conditions, and providing critical data to our space warfighters on the health and status of many satellites. Recent breakthroughs have provided outstanding images during daylight hours which allow us to support Air Force Space Command with desired information in a much shorter timeframe.

In addition, the Air Force is developing key enabling S&T capabilities for data integration, multi-sensor fusion, space object and event characterization, and threat indications and warning for enhanced SSA. The Air Force's Multi-int Activity Pattern Learning and Exploitation (MAPLE) suite of tools, already in operational use in the intelligence community, are currently being enhanced to provide advanced multi-intelligence fusion, satellite characterization, and space system behavioral analysis capabilities for "left of the event" recognition of anomalous activities for more timely warning and assessment of evolving space events. Rapid prototype fusion, characterization, assessment, and decision support capabilities have already been successfully demonstrated using passive radio frequency and electro-optical SSA data and are being further developed for planned transition to Joint Space Operations Center (JSpOC) Mission System (JMS) Increment 3.

Space Resilience

The Air Force also seeks to explore and mature a number of space resilience technologies in a relevant environment through on-orbit space experimentation. Space experimentation affords a unique opportunity to inculcate resilience into nearly all phases of the acquisition lifecycle from design and build to employment and tactical operations, while still balancing those objectives with technical risk inherent to S&T. It additionally requires integration and exercising of all space system segments (ground, link, space), providing an invaluable breadth of education for the growing base of space professionals.

Through legacy experiments such as XSS-11, TacSat-3 and ANGELS, the Air Force has demonstrated satellite resiliency concepts including responsive proximity operations ahead of inspection and satellite, repair, real time data to Combatant Commanders and monitoring of the local space environment. The Air Force's next major S&T flight endeavor is a collection of experiments called ESPA-Augmented GEO Laboratory Experiment (EAGLE) expected to launch in early Fiscal Year 2018. The host platform for EAGLE transforms a basic EELV-Secondary Payload Adapted (ESPA) ring into a highly capable satellite bus demonstrating resiliency as a space access multiplier, by hosting and/or "forward deploying" additional secondaries into optimized orbits at times of our choosing. Additionally, the concept supports growing calls for more distributed, diverse and proliferated system architectures to better enable space resilience. EAGLE will contain multiple experiments to include tactical awareness and warning, onboard anomaly assessment, deployable self-inspection capabilities, and advanced launch detection capabilities.

We are also continuing the Navigation Technology Satellite-3 (NTS-3) program, which will demonstrate a range of technologies for potential inclusion in Block 4 of the GPS constellation. Equipped with advanced digital payloads and antennas, NTS-3 is designed to provide critical PNT capabilities in GPS-denied environments. Additionally, NTS-3 is being developed to showcase the first purpose-built cyber resilient space system, and will demonstrate persistent PNT capabilities in a cyber-contested environment.

Spacecraft Propulsion

The Air Force is investing in propulsion technologies that will greatly increase the flexibility and resiliency of military satellites. Our S&T program invests in research through the regime of spacecraft propulsion to include: flight programs; advanced electric and chemical propulsion; modeling, simulation, and analysis; and plume phenomenology and signatures. The Air Force has transitioned spacecraft propulsion technologies to most of the nation's National Security Space systems since the 1980s. The latest system to be flying Air Force spacecraft propulsion technology (Hall Effect Thrusters) is the Advance Extremely High Frequency (AEHF) satellite. An AEHF satellite was recently in the news when the on-orbit Hall Effect Thrusters had to be used to put the satellite into its proper orbit when the primary orbit raising thruster failed. Most recently, the Air Force Research Laboratory, the Rapid Capabilities Office, SMC, and industry partners teamed to quickly modify and characterize the thruster (XR-5) used on the AEHF satellite and test it on orbit using the X-37B reusable space vehicle. The modified thruster (XR-5A) incorporates modifications which improve performance and operating range. The Air Force has matured Hall Effect Thrusters and is now engaging in research into multimode thrusters in the form of Field Reverse Configuration thrusters. These multimode thrusters are capable of highly efficient, low thrust operations when needed to do station keeping while simultaneously being able to provide high thrust when needed to maneuver quickly, all using a single propellant.

Rapid Innovation (Responsive) Technologies

As the Secretary of Defense recently stated, we don't have the choice between current fights and future fights—we have to do both. The Air Force S&T Program has had a long history of rapid innovation projects responding to senior leader-identified urgent needs. We have diligently refined the process based on lessons learned over nearly a decade of such projects; carefully optimized the process to rapidly produce cost-effective and operationally suitable prototypes; and leveraged Congressionally-authorized funding sources and non-traditional defense communities.

For example, the Air Force Research Laboratory Rapid Innovation Process leveraged funding authorized by Section 219 to develop the Long Endurance Aerial Platform (LEAP). LEAP provides a revolutionary, low-cost, low acoustic signature, persistent aerial ISR capability to address Combatant Command and U.S. Special Forces ISR gaps by converting a proven, fuel-efficient Light Sport Aircraft into an Unmanned Aerial System (UAS). The Air Force Research Laboratory completed the development and flight testing of the Spiral II design which has a takeoff weight of 1,650 pounds, endurance of more than 30 hours and carries a BLOS satellite communications, command and control (SATCOM C2) data relay along with day/night imaging full motion video and radio direction finding payloads. Based on the success of these tests, an operational evaluation of the system in theater was requested by U.S. Special Operations Command and funded by the Office of the Undersecretary of Defense for Intelligence. The Laboratory procured the hardware for a complete system of four air vehicles and payloads in preparation for deployment.

The Air Force S&T Program is also working to dispel the myth that rapid capabilities are always less affordable. For example, the LCAAT program is leveraging recent advances in advanced manufacturing, such as 3D printing, to rapidly design, build, and field near-term expendable or limited-life unmanned air platforms as single assets or in autonomous or manned/unmanned teams to detect, deny, and/or disrupt the enemy. This approach bends the cost curve in our favor by enabling the U.S. to deploy weapons systems to destroy or degrade the systems of our adversaries and protect those of our armed forces and of our allies at a small fraction of the cost of current manned and re-usable systems. The low cost attritable aircraft will provide an A2/AD operations capable system, and offer near-term ISR/strike capability in remote regions where forward basing is difficult or prohibited.

The LCAAT program is seeking to change the approach of the typical DoD acquisition process by enabling constant refresh and increased flexibility through close engagement and collaboration with innovative private and public businesses and revolutionary small, non-traditional businesses to reduce cycle time as well as cost. The attritable aircraft concept will offer a game-changing approach to "on-demand" system manufacturing by leveraging open systems architecture, COTS, and distributed manufacturing concepts that will reduce market barriers to entry for new technology capability and enable rapid and agile acquisition.

The Defense Rapid Innovation Program has also been an excellent means for the Air Force to communicate our areas of critical need and solicit vendors to respond with innovative technology solutions. The program continues to help us strengthen the lines of communication between the Program Executive Officers, warfighters, S&T community, and industry. We have done this under full and open competition with preference given to small businesses. We have now completed four solicitations and are in the process of making awards under the fifth solicitation. The results have been noteworthy. From the time Congress first authorized the defense rapid innovation program, the Air Force received over 3,200 white papers from all 50 states in response to our topic areas. With available funding, as of December 2015, we have invited 234 proposals and made 112 awards. Additional awards will be made this spring under the Fiscal Year 2015 program. Several of our projects have had significant success in the current fight. For example, one of our projects has more than doubled the target detection capability of our MQ-1 Predator. This capability deployed in September 2015 and is currently supporting Operation Inherent Resolve. The new capability involving Airborne Cueing and Exploitation significantly reduces analyst workload, enabling each of them to be more effective and efficient. Other agencies are benefitting from this project as well. The National Geospatial Agency is taking the results from this Defense Rapid Innovation Program effort and further expanding it to support a full spectrum capability and the Army is integrating the improved code onto their platforms.

The Air Force S&T community is also in talks to fully leverage the work of the Defense Innovation Unit-Experimental (DIUx) located in Silicon Valley, California. Researchers involved with the Air Force Research Laboratory Rapid Innovation Process have agreed to conduct "quick look" assessments of technologies discovered by the DIUx to determine validity of further collaborative engagements. The Air Force Research Laboratory Small Business Office has also begun discussions related to technology transfer processes to determine the feasibility of licensing laboratory inventions to startups and academia in Silicon Valley similar to how it is accomplished in both the Dayton, Ohio and Rome, New York areas. This office is also investigating ways to partner in the Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) realm.

EXPERIMENTATION

As discussed earlier in this statement, experimentation is truly the engine of our reinvigorated development planning efforts. It enables the unfettered exploration of alternatives in future environments and involves operators, technologists, requirements, acquisition professionals, and others collaborating from beginning to end in a truly integrated fashion. Campaigns of experimentation are not staged, one-off events; but a series of progressive and iterative activities designed to build knowledge and provides a method to rapidly evaluate capability concepts that may involve using existing systems in new ways through changes in tactics, techniques, and procedures or in new combinations with other systems and enabling technologies. The campaigns will conduct live exercises, wargaming, modeling and simulation, and virtual and hardware prototyping to assess concepts and advanced technologies. Robust experimentation enables the Air Force to explore implications of disruptive technologies and employment of existing systems and technologies in new ways.

The Air Force is currently conducting four pilot experimentation campaigns: Close Air Support (CAS); Directed Energy (DE); Data to Decisions (D2D); and Defeat Agile Intelligent Targets (DAIT). The D2D and DAIT campaigns are supporting the Air Superiority 2030 ECCT. These experimentation campaigns are designed to provide timely empirical data to enable strategic investment decisions and to reinvigorate the culture of experimentation within the Air Force.

The objective of the CAS Experimentation Campaign is to characterize the Air Force's ability to conduct CAS and explore concepts through experimentation. Results from the CAS Experimentation Campaign are expected to enhance the joint capability to perform CAS in a variety of operational environments and across a range of timeframes. The campaign formed along three distinct lines of effort: 1) localized battlefield networking; 2) JTAC and pilot simulator training enhancements; and 3) determination of the optimal mix of CAS weapons and platforms. The Air Force conducted experiments to communicate a common understanding of the battlefield between ground and air at various distances. Initial experimentation results have demonstrated that a remotely accessible internet protocol (IP) network can be used to enhance Tactical Data (Link 16) with National Technical Data and improve CAS targeting identification. CAS experimentation also improved joint training through LVC demos and enhancements. Competency based training scenarios at the JTAC Dome, which is a high-fidelity, fully-immersive, realistic training and rehearsal environment with real-time sensor, simulator, and database correlation, have benchmarked standard JTAC competencies. LVC experimentation has connected live A-10, F-16, and AH-60 platforms with virtual MQ-1s in the constructive Modern Air Combat Environment to validate JTAC training benchmarks in a Distributed Mission Operations Network. Future CAS munitions experimentation for testing on the range and in a LVC environment is also being planned. The CAS Experimentation Team is exploring emerging weapons concepts to improve the effectiveness of each pass. Several flight demonstrations are planned for Fiscal Year 2016 and Fiscal Year 2017 to ensure near-, mid-, and far-term weapons development is consistent with future CAS mission requirements.

The Air Force is also conducting the DE Experimentation Campaign to inform senior leadership on strategic investment decisions in this technology area. The Air Force S&T investment in DE technologies has placed us at a point where we can take the concepts and capabilities out of the laboratories and put them into the hands of our warfighters. The campaign is exploring a broad range of DE-enabled concepts through a series of experiments using constructive and operator-in-the-loop simulations and live exercises to understand the interplay of technologies, concept of operations (CONOPS), and doctrine in close collaboration with operators and technology developers. One effort of the DE Experimentation Campaign involves exploring the value of employing a ground-to-air DE hard kill weapon as part of an integrated air defense system. We are doing this in collaboration with the North American Air Defense Command (NORAD) of U.S. Northern Command (NORTHCOM) to explore how advanced technologies could potentially improve its National Capital region air defense capabilities. We are developing and evaluating kill chain CONOPS, performing live fire tests against multiple targets, addressing policy issues, and exploring system integration with existing command and control and guidance systems. A related effort involves experimentation with employment of an air-to-ground HEL weapon system on an AC-130 gunship. We will execute this experimentation in close collaboration with the Air Force

Special Operations Command to assess and deepen our understanding of system performance characteristics, airborne platform integration considerations, and CONOPS. In addition, we will identify and work through important policy-related issues, determine associated infrastructure requirements for a deployed system, and explore residual operational capabilities for continued experimentation and operational observations. The body of knowledge gained through these efforts will identify key risk areas and technology needs to better focus our research and accelerate the realization of HEL capabilities across a range of systems and platforms.

The two additional experimentation campaigns being planned are in response to Air Superiority 2030 ECCT direction. The D2D experimentation campaign will explore various concepts to provide the right data to decision-makers in the time and manner required and the DAIT experimentation campaign will explore new technology-enabled concepts to defeat challenging targets.

PROTOTYPING

Prototyping is a valuable tool for development planning and experimentation as it enables evaluation of design, performance and production. Prototyping activities are useful at various levels of technology maturity—specifically, concept prototypes for the early stages to assess feasibility, development prototypes to test advanced concepts and integrated capabilities, and operational/fieldable prototypes that look toward the production and deployment stage and satisfying operational needs. The Air Force has recognized that engaging operational users intimately involved in need analysis, solution conceptualization, and prototype development enables delivery of a suitable prototype with all the right attributes to satisfy the user need. Furthermore, a rapid spiral development process that incorporates experimentation and prototyping allows the design to evolve quickly based on lessons learned during operations.

One successful rapid prototyping effort is our recent project to improve Convoy C3 and Situational Awareness. In response to a request from 20th Air Force and Air Force Global Strike Command, the Air Force developed and delivered the first spiral of a convoy communications and situational awareness solution. This system provides a self-configuring, self-healing mobile network that allows the members of a nuclear convoy to share voice and text chat messages, imagery from on-vehicle cameras (including overhead imagery from supporting UH-1N helicopters), moving map displays, and reach-back to a command and control center. After approval to prototype a specific design concept was received, a prototype system was delivered in less than six months to operational users at the 90th Missile Wing, F.E. Warren AFB, Wyoming. The wing then successfully conducted a Limited Operational Demonstration and Evaluation that led to a follow-on effort to fully adopt the system and employ it at all three 20th Air Force missile wings. In parallel with this deployment to all three missile wings, the Air Force Research Laboratory implemented product improvements in the system based on lessons learned from the Operational Demonstration and Evaluation. This second spiral of the system design has been selected for full-scale development with support from Air Force Global Strike Command and the 20th Air Force. The full-scale deployment is on-track for early calendar year 2016 completion.

The Air Force's Adaptive Engine Transition Program (AETP) is building on several years of rigorous adaptive engine technology maturation, including significant industry cost share, and is an excellent example of prototyping to reduce risk prior to Engineering and Manufacturing Development (EMD). Following the highly successful S&T efforts in the Adaptive Versatile Engine Technology (ADVENT) and Adaptive Engine Technology Demonstration (AETD) programs, the AETP represents a $2 billion next generation jet engine demonstration and validation program that will advance designs through extensive ground testing for future integration and flight test. The Fiscal Year 2017 $285 million Air Force funding for this program is in Budget Activity 4

(Advanced Component Development and Prototypes). Under this effort, awards will be made to two contractors in Fiscal Year 2016. Awarding to two contractors will help ensure that the most cost-effective solutions to the challenges of engine operability, durability, sustainability, and air platform integration are achieved, while reaching the fuel efficiency and thrust goals set for the program. Additionally, two contractors developing designs will help sustain a healthy domestic and competitive industrial base, enabling the Air Force to have multiple vendors, including second and third tier vendors, to meet development and production needs for legacy and future platforms.

Since the U.S. has no monopoly on technical expertise, we are also actively engaged in the international community in prototyping efforts. Through these relationships, opportunities are identified to leverage investments, advance capabilities, produce standards for interoperability, and avoid technological surprise. For example, with the four current 5-Power Project Agreements, the U.S. invests $4.2 million each year with our partners providing an additional $8.3 million each year. These collaboration efforts have resulted this year in a new agreement with Italy and Germany to develop a prototype Small Scalable Kinetic Weapon. This real-time, adjustable UAV-delivered weapon could be used to limit collateral damage in urban environments.

On all of our efforts in this area we're working closely with AT&L's BBP 3.0 efforts to reinvigorate the use of experimentation and prototyping for the purposes of rapid fielding of technologically advanced weapons systems, providing warfighters with the opportunity to explore novel operational concepts, supporting key elements of the industrial base, and hedging against threat developments or surprises by advancing technology and reducing the lead time to develop and field new capabilities.

WORLD CLASS WORKFORCE

The world class workforce of the Air Force science, technology and engineering community continues to be our most important asset. We recognize that the technological superiority of the Air

Force depends on the technical talent and innovative spirit of our workforce. In order to maintain an agile science, technology, engineering and mathematics (STEM) workforce, two aspects have guided our investments of funding and collaborative energy this year: attracting and inspiring individuals to Air Force STEM careers, and recruiting, retaining and developing the STEM workforce.

Attracting and Inspiring STEM Talent

This past year, the governing body of Air Force STEM, the Air Force STEM Advisory Council (STEMAC), challenged its members to support a dedicated funding source for Air Force STEM outreach programs. Historically, Air Force STEM outreach programs received support through the National Defense Education Program as well as local base-level funding. The Fiscal Year 2017 Air Force S&T Program includes a dedicated effort for funding of STEM outreach activities. These funds will enable outreach programs across multiple installations to dependably offer their excellent STEM programming to K-12 students without fear of competing priorities. Additionally, the Air Force STEM Outreach Office will work toward strategic goals such as improving engagement of traditionally underrepresented communities and developing useful, relevant metrics to assess the impact of K-12 programming.

Attracting and inspiring individuals to Air Force STEM careers is a dynamic mission; as the battlefield shifts and evolves, so too do our workforce requirements. As such, Secretary of the Air Force Deborah Lee James encouraged the STEM Outreach Office to develop outreach programs to target specific technical areas. From this encouragement, the *StellarXplorers* pilot program completed its first national competition in April 2015. *StellarXplorers* is the first space-centered STEM program of its kind to challenge high school students to tackle complicated spacecraft payload flights. As the program grows, the vision is to combine simulated competition to student-led manufacturing of spacecraft hardware.

Recruiting, Retaining and Developing the STEM Workforce

Recruiting, retaining and developing the STEM workforce is vital toward building the future Air Force. The establishment of the Cyber-Spectrum Research and Technology Development Virtual Environment (CSpec-DVE) program showed great progress in this endeavor. CSpec-DVE provides the participating Air Force, Army, and Navy Reserve Officer Training Corps (ROTC) cadets exposure and a means to contribute toward cyber, electronic warfare, and signals intelligence product-oriented research. In this pilot year, 10 universities—in coordination with the Information Directorate of the Air Force Research Laboratory—will oversee and mentor the ROTC cadets. Participating universities include: Georgia Tech University, Louisiana State University, Louisiana Tech University, Syracuse University, Texas A&M University, University of Dayton, University of Houston, Rice University, Southern University and Tennessee State University. CSpec-DVE provides early career development for future leaders by enabling them to contribute to research on cyber, signal intelligence and electronic warfare technical problems.

The ability to recruit, retain and develop the Air Force STEM workforce has been greatly supported and enabled by Congress. The National Defense Authorization Acts of the past several years have provided additional personnel authorities to the S&T community. Specifically, the addition of direct hire authority for candidates with bachelor degrees has been extremely useful in hiring qualified scientists and engineers in less than half the time of traditional hiring methods. We are continuing our efforts to fully implement all of the personnel authorities provided specifically to our community by the Congress.

The Laboratory Personnel Demonstration Project continues to provide the Air Force Research Laboratory a more responsive and flexible personnel system through direct hire authorities, broad banding, the contribution-based pay system, simplified job classification, developmental opportunities, voluntary emeritus corps, among other unique workforce shaping tools. These authorities have enabled the Laboratory to successfully attract and retain high quality scientists and engineers.

To spark and foster innovation in our current workforce, the Development Opportunity Program (DOP) provides opportunities for Air Force Research Laboratory personnel to acquire knowledge, experience, and expertise that cannot be acquired in the standard working environment. Laboratory personnel have taken advantage of advanced training and education opportunities at academic institutions across the globe. Additionally, Laboratory personnel have contributed to the scientific community as visiting faculty or research scientists at various institutions. We are investigating the expansion of this program to all employees under the Laboratory Personnel Demonstration Project.

LABORATORY INFRASTRUCTURE

Infrastructure focused on S&T is an important component to support innovation and force modernization. The Air Force has made S&T infrastructure a priority as evidenced in the Fiscal Year 2016 and Fiscal Year 2017 military construction (MILCON) processes. Thanks to the approval of the Congress in Fiscal Year 2016, the Air Force Research Laboratory Space Vehicles Directorate will soon have access to a new Space Vehicles Component Development Lab. The Component Development Lab will support space vehicles component development of space power generation, solar arrays and photovoltaic cells, space power storage, space vehicle mechanisms (launch separators and maneuvering components), mechanism controls, space protection including radiation-hardened electronics, and environmental sensors and cryocoolers with four light laboratories, two medium laboratories, and class 1,000 clean rooms required for space vehicle research, development, and experiments. This new facility will consolidate 11 separate S&T infrastructures on Kirtland Air Force Base, New Mexico, increasing the effectiveness and efficiency of work accomplished by the directorate. The Fiscal Year 2017 President's Budget for MILCON includes the proposed construction of an Advanced Munitions Technology Complex on Eglin Air Force Base, Florida. This laboratory facility is integral to support research and development of sub-scale high speed munitions requiring advanced energetics containing nano and conventional materials. This laboratory would fill a need for the Air Force and the entire DoD as it would be capable of handling and using nano explosive powders or advanced energetics that use nano materials, a capability which does not currently exist in the U.S. today.

Not only has S&T infrastructure received Congressional support in the MILCON process, special Congressional authorities provided to the Laboratory Commander to conduct minor infrastructure projects, known as the "Section 219" authority, have enabled rapid improvements to S&T infrastructure. For instance, an important Section 219 project is under construction at the Air Force Research Laboratory Munitions Directorate located on Eglin Air Force Base, Florida. The Site C-86 range implements a variable height tower which will enable extended slant range measurements, full access to test range geography, optical turbulence distortion reduction, ground clutter elimination, and high value assets protection from over exposure to the elements in support of research, development, and testing of next-generation weapon seekers. This tower will support the delivery of active and passive seeker concepts to defeat adversaries in A2/AD environments as well as urban target environments and long-range targets. In addition, warfighters from Air Combat Command and Air Force Special Operations Command will benefit from use of this tower in their drive to mature technologies for killing moving targets; testing of hard and deeply buried targets seeker development; wire-strike avoidance LADAR technique; helicopter burnout solutions; and sniper identification efforts.

Congress has expanded the Section 219 infrastructure authority to permit the banking of research, test, development and evaluation funds in order to enable projects beyond minor military construction and we are working diligently to determine the best path forward within Air Force processes to implement this authority.

CONCLUSION

Chairman, Members of the Subcommittee and Staff, thank you again for the opportunity to testify today on the Air Force's move toward strategic agility in capability development through reinvigorating development planning, maximizing the impact of our robust S&T program (game-changing, enabling, relevant, and rapid technologies), increasing efforts in experimentation and prototyping, and leveraging the contributions of our entire world class workforce and infrastructure.