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STATEMENT OF: Dr. David E. Walker, SES
Deputy Assistant Secretary
(Science, Technology and Engineering)

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INTRODUCTION

Chairman Hagan, Members of the Subcommittee and Staff, I am pleased to have the opportunity to provide testimony on the Fiscal Year 2014 Air Force Science and Technology (S&T) Program. This is my first chance to address you as the Deputy Assistant Secretary of the Air Force for Science, Technology and Engineering, a position I assumed in August of 2012.

As the nature and sources of conflict throughout the globe have become more diverse and less predictable, our Nation continues to face a complex set of current and future security challenges many of which are outlined in *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense*, the defense strategic guidance issued by the President in January 2012. This guidance directed a renewed focus on the Asia-Pacific region, as well as continued emphasis on the current conflicts in the Middle East. The Air Force's enduring contributions to national security as part of the Joint team are more important now than ever before and we must remain agile, flexible, ready and technologically-advanced. Over the last year, the Air Force has aligned our S&T efforts to best support the Defense Strategic Guidance within current fiscal constraints. Our S&T Program supports the Air Force capabilities fundamental to the major priorities of the guidance, such as deterring and defeating aggression, projecting power in anti-access and area denial environments, operating in the space and cyberspace domains, and maintaining a safe, secure and effective strategic deterrent. The Air Force S&T Program plays a vital role in our Nation's security by creating compelling air, space and cyberspace capabilities for precise and reliable global vigilance, reach and power.

The Chief of Staff of the Air Force, General Mark Welsh III, recently stated in his vision for Airmen that our Service is "fueled by innovation." Our single, fully integrated S&T Program is truly at the forefront of this innovative spirit and stems from several enduring tenets. First, we must prepare for an uncertain future and investigate game-changing technologies to affordably transition the art-of-the-possible into military capabilities. To support the Air Force Core Functions, we must create technology options across a wide spectrum ranging from institutionalizing irregular warfare capabilities to providing new capabilities to operate effectively in cyberspace and across all domains. We must demonstrate advanced technologies that address affordability by promoting efficiencies, enhancing the effectiveness, readiness, and availability of today's systems, and addressing life cycle costs of future systems. In keeping with our Service heritage, we must continue to foster an appreciation for the value of technology as a force-multiplier throughout the Air Force. We must maintain the requisite expertise to support the acquisition and operational communities and modernize and improve the sustainability of unique research facilities and infrastructure. Finally, we will leverage and remain vigilant over global S&T developments and emerging capabilities to avoid technological surprise and exploit art-of-the-possible technologies for our military advantage.

AIR FORCE S&T FISCAL YEAR 2014 PROGRAM

The Air Force Fiscal Year 2014 S&T Program investments support a robust and balanced foundation of basic research, applied research, and advanced technology development that will provide demonstrated transition options to support future warfighting capabilities.

As a brief overview, adjustments were made within the S&T portfolio to focus investments in the most promising technologies to develop future warfighting capability. We are continuing emphasis in our propulsion portfolio by investing in the development of adaptive turbine engine technologies which will provide optimized fuel efficiency and increased performance capabilities over a wide range of flight regimes. We have emphasized research in hypersonics technologies and in electronic warfare areas to provide the capability to counter adversary anti-access and area denial approaches and effectively engage time sensitive targets. Based on the current and forecasted cyberspace capabilities, threats, vulnerabilities and consequences outlined in our recently published

Cyber Vision 2025 document, we aligned and emphasized our cyber S&T investment in four areas: mission assurance, agility and resilience, optimized human-machine systems, and foundations of trust. We have also emphasized the development of technologies to address limiting capability factors of human performance in military missions including autonomy, data to decisions and human systems research. I will highlight some of these adjustments later in my testimony.

AIR FORCE S&T PROGRAM PRIORITIES

The Air Force Fiscal Year 2014 S&T Program supports the following overarching priorities that are detailed in our Air Force S&T Strategy document.

Priority 1: Support the Current Fight While Advancing Breakthrough S&T for Tomorrow's Dominant Warfighting Capabilities

While developing technologies to equip our forces of tomorrow is the primary objective of any S&T portfolio, our dedicated scientists and engineers have been equally motivated over the last decade to ensuring needed technologies get into the hands of our warfighters today. This valuable near-term S&T investment has saved lives in the current fights and continues to pay dividends as we transition to other focus areas in the long term. I would like to share with you a few examples of how we have supported our warfighters over the last year and how those technologies are being poised to sustain and increase military capabilities of the future.

As an example of one method, the Air Force has executed a rapid reaction process through the Air Force Research Laboratory since 2005 which has provided rapid S&T solutions to the urgent needs of Air Force Major Commands (MAJCOMs), Combatant Commands (COCOMs) and other Defense agencies. Through focused interaction with warfighters and often partnership with other Agencies, the process leverages the breadth and depth of knowledge within the laboratory and its external "innovation network" of academia and industry to deliver accelerated technology solutions in approximately one year or less.

This rapid reaction process has been used to develop warfighting capabilities to meet United States Central Command (CENTCOM) Joint Urgent Operational Needs including efforts such as Blue Devil Block 1. Blue Devil Block 1 is a persistent intelligence, surveillance, and reconnaissance (ISR) capability demonstrating the first-ever integration of wide area field-of-view and narrow field-of-view high definition day and night sensors cued by advanced signals intelligence sensors. Imagery and data are transmitted in near-real-time to an individual soldier on the ground or a Blue Devil ground station where multiple sensor data is rapidly fused for real time cueing and decisions. This new technology and lessons learned from testing in theater will improve capabilities in future systems, especially those poised for engagements where reaction timelines and aircraft access will be more challenging. In addition, the Air Force is rapidly working a variety of S&T solutions to address MAJCOM operational needs for rapid landing site survey and preparation, improved collaboration using existing infrastructure and information, and increased global command, control and communication (C3) connectivity. The Air Force has a strong record of nurturing these types of game-changing concepts using modest S&T funds along with partnerships with customers to transition technologies quickly to warfighters while leveraging the investment to inform and enhance the development of future technologies.

Even outside of the defined rapid reaction process, the Air Force S&T Program has been instrumental in quickly bringing new or enhanced operational capabilities to warfighters worldwide. For example, we are improving awareness of the global space operations through Air Force S&T support to the Joint Space Operations Center (JSPOC) at Vandenberg AFB, California. In 2011, the Air Force Research Laboratory deployed a modern data fusion and display prototype which provides a Windows-type user interface for the 20,000 object space catalogue, modernizing from the text-based system used for the last 50 years. The prototype system provides near real-time monitoring of all orbiting U.S., commercial and foreign spacecraft assets within a common operating picture reducing operator workload while alerting them to events in a more timely fashion. It was used in October 2012 to monitor the breakup of a Russian Breeze-M rocket body and ensure that orbiting operational space assets were safe from the newly created space debris. As this technology is transitioning to the operational Air Force through the JSPOC Mission System (JMS) program at the Space and Missile Systems Center (SMC), the Air Force Research Laboratory now provides continued upgrades for space operations on tight, six-month spirals and accelerates transition of critical S&T products to Air Force capability.

The models of development for these technologies, as well as lessons learned, are now informing our research efforts to effectively manage and utilize the volumes of data created by the vast array of fielded sensors. While we have developed tools to fuse data from multiple sensors and sources to assist intelligence analysts in exploiting the data, most of these tools have not yet been integrated into our standard tactical intelligence processing system, the Defense Common Ground Station (DCGS). To facilitate this transition, we are building a Planning and Direction, Collection, Processing and Exploitation, Analysis and Production, and Dissemination (PCPAD) - Experimental Cell, or PCPAD-X. This will be an operationally-representative environment and innovative approach for research, development, experimentation, demonstration, and objective evaluation to facilitate transition of technologies for mission driven PCPAD. It will provide a realistic "analyst-in-the-loop" environment which does not exist today, complete with validated subjective and objective performance metrics, for testing potential analysis capability improvements. This environment will allow us to run existing and new analytical tools through the PCPAD-X to more quickly and affordably identify "best of breed" tools for transition.

The Air Force S&T Program is also supporting the current F-22 Raptor fleet while planning to enhance warfighter effectiveness in next generation platforms. The Air Force Research Laboratory supported the Safety Investigation Board, Scientific Advisory Board, the Root Cause

Corrective Action analysis, and is a major participant in the Air Combat Command-led F-22 Life Support Systems Task Force. To address life support issues, laboratory personnel provided expertise on oxygen systems, toxicology, aerospace medicine/physiology, epidemiology, and bio-environmental engineering. Scientists and engineers from the laboratory identified on-board oxygen generating system (OBOGS) limitations and recommended parameters for OBOGS challenge testing, resulting in a new DoD Air Quality Standard. They also developed and flew a helmet-mounted pulse oximeter for use on the F-22 in 90 days and then transitioned the design for fleet-wide operational fielding. To address multiple Air Force demand signals and future concerns due to the increasingly complex and capable fighter aircraft in development, the Air Force has begun reconstituting aerospace physiology/toxicology core competencies at the Air Force Research Laboratory. Using research and technology developed in response to the F-22 issues, this program will provide evidence-based understanding of pilot physiologic response to new air platforms, characterize physiologic performance for new flight envelopes, understand physiologic impacts due to toxic exposure, and understand unexplained cognitive dysfunction that can occur in some pilots.

Priority 2: Execute a Balanced, Integrated S&T Program that is Responsive to Air Force Service Core Functions

Our Nation depends on the Air Force to counter a broad range of threats that could limit our ability to project global reach, global power, and global vigilance. Even as we emphasize focus on the Asia-Pacific region, we are aware that we cannot predict with certainty the time, place, or nature of the next contingency where airpower will be needed. The Air Force's technological advantage is threatened by the worldwide proliferation of nuclear weapons and advanced technologies, including integrated air defenses, long-range ballistic missiles, and advanced air combat capabilities. In addition, advances in adversarial capabilities in space control and cyber warfare may limit Air Force operations in air, space, and cyberspace. Some of these technologies are attained with relatively minimal cost; greatly reducing the barriers to entry that have historically limited the reach and power of non-state actors, organized militias, and radical extremists. Today's strategic environment indicates the military need for flexibility and versatility which requires a shift to inherently agile, deployable, and networked technologies and systems—including legacy systems—designed to accomplish a multitude of missions.

Through prioritization and planning, the Air Force Fiscal Year 2014 S&T Program provides the technical edge to affordably meet these threats during this time of fiscal constraint. Since high-payoff technologies are needed to sustain our air, space, and cyberspace superiority in an increasingly competitive environment, we are smartly investing in a broad portfolio of technologies aligned with the Defense Strategic Guidance that are balanced across the warfighter's need for near-term, rapid-reaction solutions; mid-term technology development; and revolutionary, far-term capabilities.

At the Service level, the Air Force has matured its S&T planning processes a great deal over the last year by improving the alignment between S&T efforts and capability gaps outlined in Air Force Core Function Master Plans (CFMPs). Our robust research program pushes the technological state of the art across a range of areas for potential military application as well as being responsive to technology needs expressed by the operational community. The established S&T planning governance process ensures S&T investments are well understood, structured for success, and poised for transition when completed. This process is the backbone of Air Force S&T contributions to the larger DoD priorities and strategies and has provided us opportunities to lead the Department's research and strategic planning efforts in some areas including cyber, autonomy, electronic warfare and manufacturing technology. These planning efforts also support the Department's *Better Buying Power 2.0* initiatives to achieve greater efficiencies in acquisition, including developing stronger partnerships with the requirements community, using the technology development phase for true risk reduction and incentivizing productivity and innovation in industry.

To illustrate how the Air Force S&T Program is supporting our national security by providing the necessary speed, range, flexibility, precision, persistence, and lethality across all domains (air, space and cyber), I would like to highlight some of our efforts in the areas we are leading for the Department as well as across our portfolio of contributions:

Speed can contribute to survivability of Air Force systems and allow us to engage time sensitive targets even in the anti-access/area-denial environments we increasingly expect to encounter in the future. Starting in early Fiscal Year 2011, the Air Force S&T community—in collaboration with industry—developed roadmaps for high speed technology options for Air Force missions in anti-access/area-denial environments. The Air Force focused its S&T investments in two key areas: technology for survivable, time-critical strike in the near term and a far-term penetrating regional Intelligence, Surveillance, and Reconnaissance (ISR) aircraft.

Our survivable, time critical strike technology effort includes research and advanced technology development efforts that support the maturation to Technology Readiness Level 6 (TRL 6) of Mach 5.0 plus cruise missile technology. Detailed roadmaps have been developed, which include advanced guidance technology, selectable effects ordnance, airframe technology, and expendable cruise propulsion. The technologies requiring early flight testing are included in a demonstration effort that will begin later in Fiscal Year 2013 called the High Speed Strike Weapon (HSSW).

HSSW is an integrated technology demonstration that was proposed by the same Air Force and industry team who developed the overall Air Force S&T plan/roadmaps in the high speed area. Key to HSSW's tactical relevance is its compatibility with Air Force 5th generation platforms to include geometric and weight limits for internal B-2 Spirit bomber carriage and external F-35

Lightening II fighter carriage. It will also include a tactically compliant engine start capability and launch from a relevant altitude. The flight demonstration will be the first tactically-relevant demonstration of Mach 5.0 plus airbreathing missile technology. This effort addresses many of those items necessary to realize a missile in this speed regime including: modeling and simulation; ramjet/scramjet propulsion; high temperature materials; guidance, navigation, and control; seekers and their required apertures; warhead and subsystems; thermal protection and management; manufacturing technology; and compact energetic booster technologies. The Air Force is actively pursuing a partnership with the Defense Advanced Research Projects Agency (DARPA) on this demonstration to leverage their recent experience in hypersonic technologies that are relevant to HSSW and other hypersonic systems.

Analysis of challenges in the future security environment has made clear that our advanced munitions technology like the HSSW and other existing or advanced munitions will need to operate when the Global Positioning System (GPS) signal is either degraded or perhaps even denied entirely. As such, we have focused on pursuing a number of munitions guidance technologies that will allow us to continue to operate much as we have become accustomed today. These include technologies that expand upon our current anti-jam GPS navigation capabilities and novel technical approaches to navigation such as optic field flow techniques and multi-sensor fusion. These techniques allow the Air Force to harvest information regarding these systems as they traverse through their flight environment and infer the necessary navigation information.

The importance of dominance in the cyberspace domain cannot be overstated as it is a foundation for global vigilance, reach and power. Cyberspace is a domain in which, from which and through which all military missions are performed and is becoming increasingly contested or denied. The Air Force has placed great emphasis on S&T efforts to overcome threats and provide systems and methods that are affordable and resilient. The Chief Scientist of the Information Directorate of the Air Force Research Laboratory located in Rome, New York ("Rome Lab"), has been charged to chair the collaborative, Joint cyber S&T road-mapping efforts for DoD based on the Laboratory's history of exceptional cutting-edge cyber research.

Recognizing that sound strategies are the foundation for wise investments, the Air Force Office of the Chief Scientist partnered with operators and technologists from across the Air Force, government, industry, academia, National Laboratories, and Federally Funded Research and Development Centers to develop *Cyber Vision 2025* last year. *Cyber Vision 2025* describes the Air Force vision and blueprint for cyber S&T spanning cyberspace, air, space, command and control, intelligence, and mission support. It provides a long-range vision for cyberspace to identify and analyze current and forecasted capabilities, threats, vulnerabilities and consequences across core Air Force missions in order to identify key S&T gaps and opportunities. The Air Force's cyber S&T investments are aligned to the four themes identified in *Cyber Vision 2025*: Mission Assurance, Agility and Resilience, Optimized Human-Machine Systems, and Foundations of Trust. *Cyber Vision 2025* and our associated cyber S&T strategy guides the research conducted at the Air Force Research Laboratory ensuring the relevance and efficiency of our technology development for Air Force and national security users.

Air Force S&T efforts in Mission Assurance seek to ensure survivability and freedom of action in contested and denied environments through enhanced cyber situational awareness for air, space, and cyber commanders. Research efforts in automating network and mission mapping are working to provide warfighters with the ability to detect and operate through cyber attacks with threat warning, integrated intelligence, and real-time forensics/attribution. We are also focused on developing technologies to achieve cross-domain integrated effects and determine cross-domain measures of effectiveness (MOEs), including cyber battle damage assessment.

Our research in Agility and Survivability is focused on minimizing future system risk by reducing attack surfaces, segregating critical mission systems, and developing methods to contain attacks. Air Force S&T efforts are creating dynamic, randomizable, reconfigurable architectures capable of autonomously detecting compromises, repairing and recovering from damage, and evading threats in real-time. The Air Force is also enhancing cyber resiliency through an effective mix of redundancy, diversity, and fractionation (i.e., distributed functionality).

We are also working to maximize the human and machine potential through the measurement of physiological, perceptual, and cognitive states to enable personnel selection, customized training, and user-, mission-, and environment-tailored augmented cognition. Air Force S&T efforts are developing high performance visualization and analytic tools to enhance situational awareness, accelerate threat discovery, and empower task performance.

The Air Force is developing secure foundations of computing including trusted fabrication technologies, anti-tamper technologies, and supply chain assurance, as well as effective mixes of government, commercial off the shelf, and open source software to provide operator trust in systems (e.g., sensors, communications, navigation, command and control). 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 improve security at all levels of technology implementation. Further, efforts exploring high speed encryption, quantum communication and, eventually, quantum encryption will further increase the confidentiality and integrity of supporting infrastructure.

The security atmosphere of today, and that which we can visualize in the future, requires our military aircraft to operate in highly contested environments. Manipulation of the electromagnetic spectrum—called electronic warfare—can help us negate the integrated air defenses of our adversaries. Over the years, we have developed stand-off, on-board, and off-board capabilities to protect fighter and bomber aircraft; however, our adversaries continue to evolve their capabilities at the same time. As the lead for the DoD Electronic Warfare Priority Steering Committee, the Air Force has been charged to facilitate road-mapping efforts for research in new technologies and techniques to be effective against the new threats involving ways to defeat new sensors operating in new frequencies, more elaborate detection methods, and greater computational and networking capabilities of adversaries. The new technologies and techniques being created feed into Air Force and Navy upgrades to a range of military aircraft including fighters, bombers, support and decoy aircraft. For example, the Eagle Passive/Active Warning Survivability System (EPAWSS) effort for the F-15 Eagle is leveraging the Air Force Research Laboratory Sensors Directorate work in advanced digital receiver technology as one key architecture option.

Research in our Directed Energy portfolio has also shown promise in the development of capabilities to defeat our adversary’s electronic systems on the ground. In October 2012, the Air Force successfully flight tested a system called the Counter Electronics High Powered Microwave Advanced Missile Project, or CHAMP. During the flight test, the CHAMP cruise missile navigated a pre-programmed flight plan and emitted bursts of high-powered microwaves at targets containing a wide range of representative electronic equipment, effectively delivering a functional disable of the systems without harmful effect on people or structures in and around the target area. This successful test culminated the CHAMP Joint Capabilities Technology Demonstration (JCTD) and moved the Air Force closer to providing combatant commanders with a non-kinetic counter electronics capability as a complement to lethal measures, increasing mission options for the warfighter.

The Defense Strategic Guidance pivot to emphasis on the Asia-Pacific region means missions with expanded duration, intermittent communication disruptions, high rate of changing situations, and a larger array of asset capability. These realities require research in both human systems and performance to better enable warfighters to enhance military capabilities as well as autonomous systems which can extend human reach by providing potentially unlimited persistent capabilities without degradation due to fatigue or lack of attention. Since they are investment priorities, the Department has established cross-Service steering groups for both human systems and autonomy to roadmap and coordinate research efforts in these areas. The Air Force is leading the autonomy steering group and is an active member of the human systems group.

The Air Force envisions that the greater use of autonomous systems will enable United States forces to operate well within the "decision loops" of our adversaries. Such increases in machine autonomy will require humans and automated systems to work as a team, with some level of decision-making delegated to the machine counterpart. We seek to enable the *right balance* of human and machine capability to meet Air Force challenges in the future and are focused on growing autonomous system capability, integrated with the human capacity to perform in a high-tempo, complex decision environment, and to optimize humans working together with machines, both effectively and efficiently.

To achieve this, 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/capabilities of the other. The keys to maximizing this human-machine interaction are: instilling confidence and trust among the team members; understanding of each member's tasks, intentions, capabilities and progress; and ensuring effective and timely communication. This must all be provided within a flexible architecture for autonomy, facilitating different levels of authority, control and collaboration. Current research is focused on understanding human cognition and applying these concepts to machine learning. For example, we are developing efficient interfaces for an operator to supervise multiple MQ-9 Reaper platforms and tools for ISR analysts to better identify and track targets of interest. We are also conducting human systems research in the areas of decision-making, training, bioeffects, and human-centered ISR. We have increased our emphasis in training research with the objective of providing live, virtual, and constructive (LVC) rehearsal capabilities to increase affordability by reducing training time by 30 percent, increasing training effectiveness by 15 percent, and creating common methods for cross-mission application. As a result of this research, the Air Force will be more efficient and effective while tailoring training and rehearsal to the point-of-need to keep pace with rapidly evolving and complex threats.

Today there is little cross-platform interaction or coordination without a human engaging in the interaction. Therefore, the Air Force is developing cooperation technologies that will allow machines to autonomously synchronize activity and information to take our military capabilities beyond human limitations. Systems that coordinate location, status, mission intent, intelligence and surveillance data can provide redundancy, increased coverage, decreased costs and/or increased capability. The Air Force's research efforts are focused on developing control software to enable multiple, small unmanned air systems to coordinate mission tasking with other air systems or with ground sensors and also on 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, and cooperate to achieve optimum effects.

The Air Force's mission to *fly*, *fight* and *win* in air, space and cyberspace, requires a tremendous amount of energy. In fact, our Service uses approximately 2.5 billion gallons of aviation fuel per year and is the largest fuel consumer in the federal government. As such, we are pursuing research into technologies to reduce energy demand for both legacy and future aircraft.

For example, in conjunction with Air Mobility Command, the Air Force Research Laboratory is conducting promising research to reduce drag on C-130 Hercules aircraft, one of the primary fuel consumers in our legacy fleet. This low-cost aft-body flow control research, consisting of microvanes and finlets, will reduce the flow separation around the cargo ramp and the horizontal junction with the fuselage. Flight testing to date has shown that these devices can save three to five percent of total aircraft drag during normal flight conditions. The Air Force has developed and funded a two-phase flight test process to optimize the design of the devices to provide the maximum fuel savings possible without having detrimental effects on airdrop operations, basic loadability, handling qualities and structural dynamics. Phase I (early operational assessment) testing was successfully completed at Yuma Proving Ground in November 2012. Phase II (fuel flow, handling qualities and structural dynamics) testing is on schedule for late spring of this year. This modest research investment could save approximately $130,000 per year, per aircraft and the resulting production versions are installable at the field level, meaning minimal downtime for the warfighter and depot level maintenance savings.

For the longer term reduction in energy demand, the Air Force is investing in the development of adaptive turbine engine technologies which have the potential to reduce fuel consumption by 25 percent in comparison to current turbine engines by enabling optimized performance over a wide range of flight conditions. These technologies also increase capability in anti-access/area denial environments by increasing range by 25 to 30 percent or increasing time-on-station by 33 to 40 percent.

The Air Force initiated investment in adaptive engine technology through the Adaptive Versatile Engine Technology (ADVENT) program. This research is being leveraged by our current Adaptive Engine Technology Development (AETD) program. AETD will mature ADVENT and additional technologies, including inlet and exhaust systems, to TRL 6 to reduce risk for follow-on activities and facilitate integration into multiple platforms to realize operational benefits. Investments in these efforts helps us reduce energy demand, bridge the “valley of death” between S&T and potential acquisition programs, and help maintain the U.S. industrial technological edge and lead in turbine engines.

The Air Force is also the lead for the Department in the development and demonstration of technology solutions that decrease manufacturing risk and increase weapon system affordability for aerospace propulsion, structures and ISR systems. Simply stated, a more capable and lean warfighting force requires a much more efficient and responsive manufacturing and industrial base than we currently have today. The Air Force Manufacturing Technology program explores strategic issues and opportunities in manufacturing and industrial readiness including moving manufacturing considerations to bear earlier in the design cycle to reduce acquisition cost and risk; enabling a seamless life-cycle value stream management through a cradle-to-cradle digital design thread to improve process control, optimization, and agility; integrating the industrial base enterprise to predict, identify, and react to supply chain issues; and creating the factory of the future with flexible, robust tooling and machine cells for limited part runs.

For example, the Air Force Manufacturing Technologies program conducts Manufacturing Readiness Assessments on new technology, components, processes, and subsystems in order to define the current level of manufacturing maturity and identify associated risk. A number of major DoD weapon system suppliers and Original Equipment Manufacturers (OEMs) have integrated manufacturing readiness levels into their gated technology transition processes to help decide when a technology is mature enough to use in a product design. As a result, prime contractors and other OEMs are making better decisions about which technologies to include in product designs resulting in reduced cost, schedule and performance risk. This past year, the advanced manufacturing propulsion initiative continued activities to reduce the weight and cost of turbine engines through advanced manufacturing of light weight castings and ceramic composites. The advanced next generation radar and coatings affordability projects continue to reduce technology cost and manufacturing risk to systems such as the F-22 and F-35 aircraft.

The Air Force S&T Program is also supporting the President's Materials Genome Initiative (MGI) aimed at doubling the speed and reducing the cost of discovering, developing and deploying new advanced materials. The MGI is engaging all stakeholders in the materials development community which spans academic institutions, small businesses, large industrial enterprises, professional societies, and government. Our supporting effort is called Integrated Computational Materials Science and Engineering (ICMSE) and its objective is to develop quantitative and predictive techniques for the field of materials science and engineering (MSE) to bring similar benefits to MSE that have been realized from Finite Element Analysis or Computational Fluid Dynamics in aircraft design.

ICMSE requires new, science-based capabilities in order to create fresh approaches for the design of materials. Coupled with materials design is the need to develop a robust, two-way conduit between materials design, manufacturing, and component design. The Air Force, Johns Hopkins University, and the University of Illinois have teamed to form a center-of-excellence (COE) to innovate new solutions for pervasive ICMSE issues, including physics-based multi-scale modeling and uncertainty quantification. While the COE explores basic science underpinnings for ICMSE, nearer-term approaches to integrate the continuum spanning materials design and vehicle design are being explored in concert with vehicle/component designers, manufacturers, materials suppliers, and materials developers. Two Air Force-relevant engineering problems (high-temperature metals and composites) establish the scope on which to develop, test and demonstrate approaches for ICMSE.

Research in our space portfolio also addresses how to accomplish the Air Force mission with resiliency and affordability. For example, we are seeking to provide added protection to our satellites by increasing the robustness and resiliency of the most susceptible spacecraft components which will provide affordable options for a more-defendable space capability. The Air Force collaborates with NASA on research in space communications to extend the frequency trade space and create options for future space communication satellites. We are also continuing to mature technology for next-generation GPS user equipment with anti-jam capability for contested theater operations, including the transitioning of the cold atom technology from basic to applied research which offers great promise for operating in GPS-denied environments. In the space situational awareness area, the Air Force S&T enterprise operates two 3.5 meter class telescopes and several smaller ones that, as well as performing research, are used to support satellite owners in determining the health/status of their satellites using high resolution optical images instead of the traditional radar.

To reduce the cost of space access, the Air Force is researching ways to improve Evolved Expendable Launch Vehicle capability through increased use of multiple payloads. Air Force S&T maintains a long-term investment in pervasive spacecraft technologies, such as more efficient space solar cells that can reduce solar array mass by 40 percent.

Space experiments, such as the current Advanced Responsive Tactically Effective Military Imaging Spectrometer payload on TacSat-3 and the Communications/Navigation Outage Forecasting System, are a critical tool used to develop and prove new technologies and phenomenologies. Future experimental satellites include the Automated Navigation and Guidance Experiment for Local Space, which will research local space surveillance, and the Demonstration and Science Experiment, which will research approaches to counter a space nuclear detonation.

Development of revolutionary, far-term capabilities begins with scientific discovery and the building of foundational knowledge with our investment in basic research. Based on visions of the future established by Air Force leadership, Air Force scientists and engineers identify, nurture and harvest the best basic research to transform leading-edge scientific discoveries into new technologies with substantial military potential. These technologies transform the art-of-the-possible into near-state-of-the-art and offer new and better ways for the acquisition community to address far-term warfighter needs. While it can be more of a challenge to quantify long-term basic research, with the scientists and engineers at the Air Force Office of Scientific Research within the Air Force Research Laboratory actively engaged in worldwide technical communities, the Air Force has leveraged significant investments made by other defense and federal agencies, as well as non-defense and international laboratories, in its on-going efforts to advance basic science.

For example, an Air Force basic research funded project in quantum storage at the University of Maryland has demonstrated for first time that multiple images can be stored and retrieved at different times based on interaction between light and matter. In this atomic memory, light signals can now be stored as patterns in a room-temperature vapor of atoms that are tailored to absorb and later re-emit messages on demand. Quantum storage capabilities will exploit quantum effects for computing and communications are vital to increasing the speed, capacity and security of our networks and computer systems of the future. The researchers are continuing to understand entangled quantum memories for use in securing long distance transmission of secure information through optical fiber systems.

While most of our investments in the Air Force S&T Program focus on developing and advancing technologies for the future, S&T also has an important role to play in providing technology options to increase the availability and decrease the life cycle costs of our legacy platforms now. Many of the Air Force's current aircraft were manufactured decades ago and are experiencing age-related issues, such as cracking and corrosion, especially after nearly 20 years of unabated use. Our S&T efforts to address sustainment issues not only pay dividends now but also provide options when designing and building future systems. We are focusing our sustainment efforts in three areas: inserting new technologies in legacy systems to better and more affordably sustain the fleet, developing technology-based approaches to improving fleet health management and introducing new design approaches for future systems and components.

For example, over the last year our research had yielded results in addressing critical cracking issues with the C-5 Galaxy aircraft floor bulkhead end fittings. The cracks, caused by stress corrosion, led to increased maintenance costs and reduced the amount of cargo that could be carried on the aircraft. Using a new, more stress corrosion-resistant aluminum alloy, researchers developed a new die forging process by which all of the 92 fitting shapes required for the C-5 bulkhead could be produced using only two separate forging dies. The new technology, which has now been transitioned to the Warner Robins Air Logistics Center, provides many benefits including a 25 percent overall cost savings, an 80 percent reduction in fabrication time and a 60 percent increase in service life of the fittings.

The Air Force is also a key member of the multi-Service Advanced Technology Demonstration (ATD) addressing propulsion sustainment for current and future aircraft. The team is working to provide hot section component durability which is a significant driver of maintenance costs. This effort is focused on advanced turbine cooling and aerodynamics technologies that reduce weight and allow engines to run hotter at the same material temperature thereby producing more thrust. These types of technologies are aimed at benefitting turbine engine programs across DoD including current programs, such as the F-35, as well as future Air Force programs, such as the Long Range Strike bomber.

Priority 3: Retain and Shape the Critical Competencies Needed to Address the Full Range of S&T Product and Support Capabilities

The U.S. Air Force is the most technologically advanced air force in the world – and we intend to keep it that way. Technology is part of every mission we perform, and innovative and technically-savvy Airmen are our most important asset. The Air Force ensures we continue to have war-winning technology by careful and proactive management of our Science, Technology, Engineering, and Mathematics (STEM) workforce.

Through implementation of *Bright Horizons*, the Air Force STEM Workforce Strategic Roadmap, and the Air Force Systems Engineering Strategic Plan, we continue to develop and retain a workforce with the skill sets necessary to create compelling air, space and cyberspace capabilities for precise and reliable global vigilance, reach and power. The Air Force is progressively developing a highly qualified engineering workforce with the engineering competencies required to support the acquisition of warfighting systems. We continue to be appreciative of the Laboratory Demonstration authority and are investigating opportunities to expand the program to our entire STEM workforce.

The Air Force conducted an in-depth review of our STEM requirements and is revamping our accession and recruiting processes to help career field managers obtain the right skill sets. Over last eight years in the Science, Mathematics, and Research for Transformation (SMART) Scholarship Program, the Air Force averaged 60 scholarships per year to scientists and engineers; after payback commitment, we retained 88 percent of scholars in Air Force jobs. Through an innovative Section 219 (of the Duncan Hunter National Defense Authorization Act of 2009) workforce initiative, the Information Assurance Internship funds 10 to 20 college juniors and seniors in STEM disciplines to study the science of information assurance and information warfare on Air Force problems. For instance, last year's interns, who averaged a 3.8 grade point average, developed a mathematical model for the MQ-9 Reaper remotely piloted vehicle in a contested cyber environment. The Air Force utilizes this initiative to attract and offer employment to the best and brightest cyber students. An objective of our workforce strategy is to improve the pool of diverse candidates available to enter our STEM workforce. We also continue to have a vibrant relationship with Historically Black Colleges and Universities and Minority Serving Institutions (HBCU/MI), who conduct research projects, improve infrastructure, and intern with the Air Force Research Laboratory in support of the Air Force mission. The Air Force uses essential tools, such as the SMART Program and the Information Assurance Internship, to renew and grow the required skill sets critical for Air Force mission success. The Air Force remains dedicated to improving our force management processes to attract, recruit and retain STEM talent.

Priority 4: Ensure the Air Force S&T Program Addresses the Highest Priority Capability Needs of the Air Force

As discussed earlier, the Air Force S&T planning and governance process ensures the Air Force S&T program addresses the highest priority capability needs of our Service. The Air Force Core Function Master Plans (CFMPs) play a critical role in this process by identifying S&T needs as they relate to capability gaps, requirements, and potential materiel solutions.

Among other things, this process has allowed us to create and execute Air Force Flagship Capability Concepts (FCCs). Key factors in commissioning this type of an Air Force-level technology demonstration effort include having a well-defined scope and specific objectives desired by a MAJCOM. The technologies are matured by the Air Force Research Laboratory with the intent to transition to the acquisition community for eventual deployment to an end user. These FCCs are sponsored by the using command and are vetted through the S&T Governance Structure and Air Force Requirements Oversight Council to ensure they align with Air Force strategic priorities. Currently, the Air Force is working on three FCCs: the High Velocity Penetrating Weapon

(HVPW), Precision Airdrop (PAD), and Selective Cyber Operations Technology Integration (SCOTI).

The HVPW FCC was established to demonstrate critical technologies to reduce the technical risk for a new generation of penetrating weapons to defeat difficult, hard targets. This FCC is maturing technologies that can be applied to the hard target munitions acquisition including guidance and control, terminal seeker, fuze, energetic materials and warhead case design. This effort is developing improved penetration capability of hard, deep targets containing high strength concrete with up to 2,500 feet per second (boosted velocity) impact in a GPS-degraded environment. This technology will demonstrate penetration capability of a 5,000 pound-class gravity weapon with a 2,000 pound weapon thus increasing the loadout for bombers and fighters. Testing in 2013 has demonstrated warhead survivability and several sled tests are scheduled for the first quarter of Fiscal Year 2014.

The PAD FCC was commissioned in 2011 in response to a request from the Commander of Air Mobility Command for technologies to improve airdrop accuracy and effectiveness while minimizing risk to our aircrews. The Air Force Research Laboratory, Aeronautical Systems Center, and Air Mobility Command members established a working group to explore all aspects of the airdrop missions from re-supplying our warfighters in the field to providing humanitarian aid to people in need across the globe. To date, PAD FCC efforts have focused on: early systems engineering analysis to determine major error sources, data collection, flying with crews, wind profiling, designing high density pallet rollers, and designing modeling and simulation (M&S) activities. We expect demonstrations to begin in late calendar year 2013.

The SCOTI FCC is executing smoothly toward providing cyber technologies capable of affecting multiple nodes for the purposes of achieving a military objective. SCOTI directly meets the needs of a major capability area in the Air Force Cyberspace Superiority Core Function Master

Plan and provides a non-kinetic alternative to an adversary's operations. The standardized delivery platform being developed is scheduled to be complete in Fiscal Year 2013 and will serve as a baseline for current and future integrated cyber tools. The SCOTI stakeholders signed the finalized Technology Transition Plan in March, clearly identifying how SCOTI is expected to transition to the warfighters for operational use. SCOTI is on track to be delivered to the Air Force Life Cycle Management Center in Fiscal Year 2013 for integration with additional mission software, and Initial Operational Capability can be achieved as early as Fiscal Year 2016. In the past year, the stakeholders also completed SCOTI's Test Master Plan, and warfighters from the 166th Air National Guard conducted system-level tests on two development spirals of SCOTI technology with positive results. SCOTI is on track to meet all eight of its technical performance measures and provide the desired capability to the warfighter.

To ensure these FCCs and other advanced technology development efforts are postured for successful transitions to warfighting capability, the Air Force is continuing deliberate efforts to better align S&T planning, technology transition planning, and development planning. The linkages between these planning activities are critical to initiating acquisition programs with more mature technologies and credible cost estimates, and we are mandating this linkage in new Air Force policy.

The Air Force is also engaging small businesses through the Rapid Innovation Fund (RIF) to rapidly insert innovative technologies into acquisition programs that meet critical national security needs. In the first year (Fiscal Year 2011), the Air Force solicited innovative technologies in five broad thrust areas for this program: 1) Rapid Fielding to Support Overseas Contingency Operations, 2) Cyberspace Superiority and Mission Assurance, 3) Improved System Sustainment, 4) Power Generation and Energy for Platforms and 5) Joint Urgent Operational Needs (JUON) with an Air

Force interest. After receiving 729 white paper proposals from vendors in 44 states, the Air Force awarded 46 contracts, all of which went to small businesses.

We have experienced a similar reaction from industry to our Fiscal Year 2012 RIF broad agency announcement which solicited innovative technologies from more than 40 thrust areas submitted by the Air Force's Program Executive Offices (PEOs). The more than 700 white paper proposals received will be evaluated by a team from across the Air Force. We expect to make award notifications for the Fiscal Year 2012 RIF program in the spring of this year.

Overall, the Rapid Innovation Fund presents an opportunity to transition innovative technology into Service programs. The Rapid Innovation Fund provides a vehicle for businesses (especially small businesses) to easily submit their innovative technologies where they feel it will best meet military needs. The Air Force benefits by having the ability to evaluate proposed innovative technologies against critical needs and selecting the most compelling for contract award.

Through the Small Business Innovation Research (SBIR)/Small Business Technology Transfer (STTR) Program, the Air Force continues to garner the creative, innovative, and entrepreneurial spirit of small businesses to solve many technological problems. In that regard, we are pleased that the SBIR program was reauthorized through 2017 and many of its provisions expanded or made permanent. As we implement the provisions of the reauthorization, we intend to collaborate with other Federal agencies, where practical, to ensure that our processes are streamlined, efficient, and that small businesses continue to be a major driver of high-technology innovation and economic growth in the United States.

CONCLUSION

Our emphasis areas reflect our re-focused S&T portfolio given budgetary challenges and the Defense Strategic Guidance. I believe these areas also reflect the promise of future warfighting capability enabled by the technologies that will be developed with Air Force S&T Program investment. We recognize that these challenges will not disappear tomorrow, and that is why we have improved our processes to make better investment decisions and to capitalize on these investments to efficiently deliver capability to our warfighters. We continue to institutionalize these initiatives in our policies and procedures across the Air Force. The S&T portfolio we present to you today, after all, is the genesis of our warfighting capability of tomorrow. Our Airmen and our Nation are depending on it!

Chairman Hagan, thank you again for the opportunity to testify today and thank you for your continuing support of the Air Force S&T Program.