UNITED STATES
AIR FORCE

TIME – SPACE – COMPLEXITY

SCIENCE AND TECHNOLOGY STRATEGY

STRENGTHENING USAF SCIENCE AND TECHNOLOGY FOR 2030 AND BEYOND

APRIL 2019

CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

Introduction

Great power competition is the central challenge to U.S. prosperity and security. A rapidly growing China and resurgent Russia aim to coerce their regional neighbors, undermine long-standing alliances, and displace American influence from critical regions around the globe. These great power competitors are challenging U.S. dominance in all warfighting domains: air, land, sea, space, and cyberspace.

Over the past several decades, the U.S. Air Force's science and technology enterprise focused on developing technical advances to enhance operational effectiveness. The goal was to confer an unprecedented force multiplication advantage to the military—do more with less. This focus remains an important component of the Science and Technology Strategy. However, the Air Force now operates in a changed strategic environment.

The globalization of technology now allows potential adversaries access to cutting-edge science and technology research and the best science and technology talent. As they work toward reaching technological parity, they also push to erode our military's technological superiority.

Vision for 2030 and Beyond

The guiding vision of this Strategy is an **Air Force that dominates time, space, and complexity in future conflict across all operating domains to project power and defend the homeland**. This means the Air Force operates at an unrivaled speed. It achieves unparalleled global awareness, reach, and effect. It harnesses the power of complexity, presenting the adversary with an ever-growing number of challenges that demand resource prioritization, increase vulnerabilities, and impart overwhelming confusion.

The National Defense Strategy calls for building "a more lethal, resilient, and rapidly innovating Joint Force." The 2030 Science and Technology Strategy aligns with this call, but it also requires transformational strategic capabilities that must be driven by scientific and technological advances.

Rather than reacting to others' advances, the Air Force will set an unmatched pace. Instead of looking at where potential adversaries are heading, the Air Force scientific and technical enterprise will predict where adversaries cannot easily go and then ensure the Air Force gets there first.

Three Objectives

The plan for executing this Strategy is divided into three objectives and the supporting reforms that will help drive toward the new vision. The three objectives are as follows:

- Objective I: Develop and Deliver Transformational Strategic Capabilities

- Objective II: Reform the Way Science and Technology Is Led and Managed
- Objective III: Deepen and Expand the Scientific and Technical Enterprise

Each of these objectives is an integral element necessary to make the vision a reality. They also directly support all three lines of effort tasked by the National Defense Strategy:

(1) Build a more lethal force.

(2) Strengthen alliances and attract new partners.

(3) Reform the U.S. Department of Defense for greater performance and affordability.

Objective I: Develop and Deliver Transformational Strategic Capabilities

The Air Force will focus on developing and delivering transformational, operational capabilities by restructuring its science and technology portfolio and management processes, enhancing the competition for ideas and sustaining an enabling and enduring scientific and technical base.

Two components are needed in the Air Force scientific and technical portfolio—a broad-based, enabling, and enduring component and a focused transformational component. The broad-based, enabling, and enduring component aligns to technical disciplines of enduring importance to the United States as a global air and space power. The transformational component will focus on five **strategic capabilities** that directly support the vision to dominate time, space, and complexity across all operating domains. The five strategic capabilities are as follows:

1. Global Persistent Awareness
2. Resilient Information Sharing
3. Rapid, Effective Decision-Making
4. Complexity, Unpredictability, and Mass
5. Speed and Reach of Disruption and Lethality

The transformational science and technology component will advance technology solutions along these capabilities and include a set of focused research programs called **vanguards**. Vanguard programs will aim for significant technical achievements that demonstrate the viability of leap-ahead capabilities.

Objective II: Reform the Way Science and Technology Is Led and Managed

The Air Force proposes to reform the way we lead and manage through the appointment of a Chief Technology Officer. Our intention is to elevate the advocacy for science and technology within the Air Force. The Chief Technology Officer will guide strategic scientific and technical decisions, prioritize activities, and coordinate across the Service to effectively convert scientific and technical investments into new disruptive capabilities.

Objective III: Deepen and Expand the Scientific and Technical Enterprise

The Air Force will deepen and expand the enterprise by engaging the workforce and leveraging partnerships with partner organizations. Enhancing the recruitment of national and global talent, advancing workforce development, creating a stronger pipeline of technology-proficient military airmen, and implementing agile workforce practices will significantly strengthen Air Force scientific and technical expertise. Expanding the Air Force's scientific presence in innovation hotspots, funding research in universities and with partnerships, creating a more visible Air Force science and technology front door, and strengthening partnerships increases discovery, innovation, and technology transition. We will strengthen the workforce and strengthen our connections to the broader scientific enterprise.

Call to Action

Technological parity is insufficient to maintain U.S. military superiority. The Air Force Science and Technology enterprise must set the pace to drive the Air Force toward the vision of dominating time, space, and complexity across all operating domains. Through immediate and sustained commitment to the objectives of the 2030 Science and Technology Strategy, the Air Force will embrace this new mindset and continue to develop and deliver disruptive innovations to ensure our nation's defense.

"The advantage will go to those who create the best technologies and who integrate and field them in creative operational ways that provide military advantages."

— Heather Wilson
U.S. Secretary of the Air Force

"Challenges to the U.S. military advantage represent another shift in the global security environment. For decades, the United States has enjoyed uncontested or dominant superiority in every operating domain. We could generally deploy our forces when we wanted, assemble them where we wanted, and operate how we wanted. Today, every domain is contested—air, land, sea, space, and cyberspace." – 2018 National Defense Strategy

INTRODUCTION: CHALLENGES TO TECHNOLOGICAL SUPERIORITY

A changing strategic environment threatens the technological superiority of U.S. military forces. As a result, this threatens our military's strategic and operational advantages.

Within the past two decades, the Air Force primarily supported military operations against non-state adversaries armed with relatively unsophisticated technologies. During this time, the Air Force continued to develop and leverage science and technology to modernize the force. However, the primary focus supported existing warfighting concepts to address near-term capability gaps and enhance operational effectiveness. Evolutionary technological improvements sufficiently maintained superiority.

Now, great power competitors are once again challenging the Air Force's ability to project power and protect U.S. interests and those of our allies. They are aggressively modernizing and expanding their offensive and defensive capabilities in every domain and in ways specifically designed to threaten key components of Air Force power projection. These components include forward bases; maintenance and supply; combat aircraft; and high-value aircraft and spacecraft providing command, control, intelligence, surveillance, and reconnaissance.

These potential adversaries use science and technology to match U.S. capabilities and work to erode its military's technological superiority. Emerging technology that is more globally accessible enables them to develop new integrated air defenses, mobile missile systems, long-range weapons, nuclear capabilities, anti-satellite systems, and concealment and deception means. Improving their computing capabilities enables adversaries to better match traditional U.S. military speed and agility and maintain awareness of the battlespace. They are expanding warfare to contest new domains, especially in space and cyberspace.

Most of today's scientific and technical activities are conducted outside the U.S. Department of Defense, across the global landscape. Many of the technologies that enable emerging Air Force capabilities, such as advanced computing and wireless networking, are driven by commercial investments that exceed Defense Department resources. The globalized technology marketplace helps competitors quickly upgrade their military capabilities and narrows our technological advantage.

The Need for Change

The National Defense Strategy calls for the Joint Forces to defend the homeland and deter aggression within the context of long-term strategic competition against rapidly modernizing state adversaries. Across its core missions, the Air Force faces an increasingly dynamic, contested, and complex environment. Adversaries will project power and contest access to all

domains using long-range, mobile power-projection forces that will be difficult to find and target. This places the current force structure, which emphasizes relatively low numbers of high-value assets, at risk.

Protection and resilience must be built into power projection assets. In addition, within highly dynamic battlespaces, actionable information must be rapidly gathered to drive disruptive effects despite adversaries' capabilities to contest access and hold friendly forces under the constant threat of sustained attack. Air Force capabilities emphasize speed, stealth, and expeditionary sustainment. To fight and win in the future, the Air Force must expand those strengths with greatly enhanced resilience, agility, persistence, and reach to overwhelm potential adversaries anywhere in the world.

Vision

An Air Force that dominates time, space, and complexity in future conflict across all operating domains to project power and defend the homeland.

Mission

Provide airmen the scientific and technological advances needed to deter war and protect vital national interests.

The vision of this Strategy is an Air Force that dominates time, space, and complexity in future conflict across all operating domains to project power and defend the homeland. This means the Air Force operates at an unrivaled speed. It achieves unparalleled global awareness, reach, and effect. It harnesses the power of complexity, where complexity means our forces present the adversary with a growing number of potential challenges, in peacetime as well as during active conflict. A major goal is to force the adversary to confront multiple dilemmas. However, at a minimum, the adversary is pushed to devote resources toward things it may or may not ever confront. By owning complexity, the Air Force will present the adversary with an ever-growing number of challenges that demand resource prioritization, increase vulnerabilities, and impart overwhelming confusion.

Changes in the scientific and technical enterprise are essential to realize this vision and create the Air Force of the future. The Air Force previously leveraged science and technology to achieve military superiority by developing transformational, leap-ahead capabilities such as supersonic flight, intercontinental ballistic missiles, stealth, and precision-guided weapons. The United States retains its technological advantage by demonstrating transformational military technologies and disruptive warfighting capabilities that render earlier concepts obsolete. Yet, it is exceptionally difficult to predict which technological breakthroughs will occur. This Science and Technology Strategy will enable the agility necessary for technological advances to rapidly evolve into transformational Air Force capabilities.

Context for Action

Recognizing the challenges of an increasingly complex global security environment, the Secretary and the Chief of Staff of the Air Force directed the Air Force to develop and implement a new Science and Technology Strategy for the Air Force. The following three questions guided this Strategy:

1. What basic and applied research areas should the Air Force focus on to ensure U.S. national security advantage in air, space, and cyberspace domains in 2030?

2. What methods, processes, and organizational structures best enable the Air Force's scientific enterprise to effectively manage an exceptional research enterprise and effectively engage university and industry partners?
3. How do large innovative organizations exploit rapidly developing science and technology, and how should the Air Force adjust processes and organizational structures to improve rapid transition into effective weapons systems?

In response to these questions, the Air Force conducted a comprehensive assessment of scientific and technical opportunities relevant to Air Force needs by canvassing leaders and experts across the nation. This was coupled with a top-down analysis of the overarching capabilities the Air Force must bring to the Joint Services fight supporting the National Defense Strategy and the science and technology to enable those capabilities. A parallel assessment focused on a wide-ranging review of scientific and technical execution with leading private and public-sector organizations.

This three-part Strategy envisions an Air Force scientific and technical enterprise that continually drives new warfighting capabilities through transformational, multidisciplinary, systems-of-systems innovation.

First, the Air Force will restructure its scientific and technical portfolio and management processes to deliver multidisciplinary, transformational advances in Air Force capabilities and enhance competition to uncover the best ideas and technologies while sustaining a vigorous base of Air Force-critical science and technology that is enabling and enduring.

Second, the Air Force will propose to elevate the voice of science and technology within Air Force leadership for strategic decision-making commensurate with its importance to future warfighting competitiveness.

Third, the Air Force will expand and deepen its access to scientific and technical talent through internal workforce enhancement and stronger partnerships across the national and international enterprise.

"The first essential of airpower necessary for our national security is preeminence in research."

— General Henry H. "Hap" Arnold
Commander, U.S. Army Air Forces, World War II

"To succeed in the emerging security environment, our Department and Joint Force will have to out-think, out-maneuver, out-partner, and out-innovate revisionist powers, rogue regimes, terrorists, and other threat actors." – 2018 National Defense Strategy

OBJECTIVE I: DEVELOP AND DELIVER TRANSFORMATIONAL STRATEGIC CAPABILITIES

This Air Force recognizes the need for two components of the investment portfolio that are appropriately balanced—a broad-based, enabling, and enduring component driven by technological opportunities and gaps in capabilities and a more focused transformational component driving future force design. The enabling and enduring component largely exists today.

This component of the scientific and technical enterprise focuses on discovering new technology of Air Force relevance, identifying solutions to established Air Force mission gaps, maturing emerging technology into Air Force systems, and responding to urgent needs. It encompasses basic research (Budget Activity [BA] 1), applied research (BA2), advanced technology development (BA3), and advanced component development and prototypes (BA4) (see Figure 1).

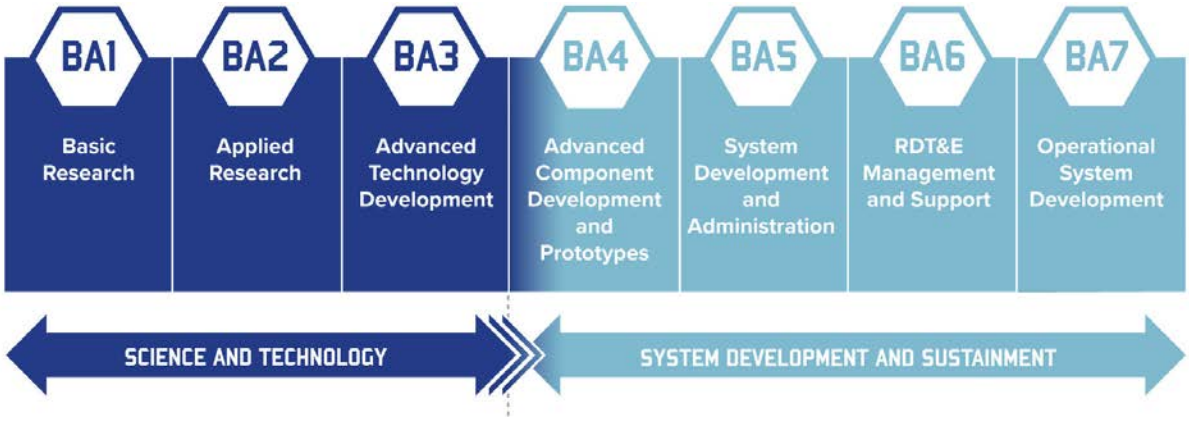


Figure 1. Definition of Science and Technology Within the Overall Spectrum of Air Force Research, Development, Test, and Evaluation Activities.

The Air Force Research Laboratory is an essential and central component of this enabling and enduring research component. The current science and technology investment portfolio is organized, funded, and managed using a structure aligned to technical disciplines, specifically the technology directorates comprising the Air Force Research Laboratory. While appropriate for enabling and enduring science and technology, this structure is not well suited for developing the transformational, multidisciplinary, system-of-systems technology solutions needed to enable new Air Force warfighting capabilities. Therefore, the Air Force will allocate a dedicated fraction of its overall science and technology budget to a transformational component of the portfolio and manage this component independently. The initial target for the transformational portfolio is at least 20% of the annual science and technology budget. This target may be modified over time.

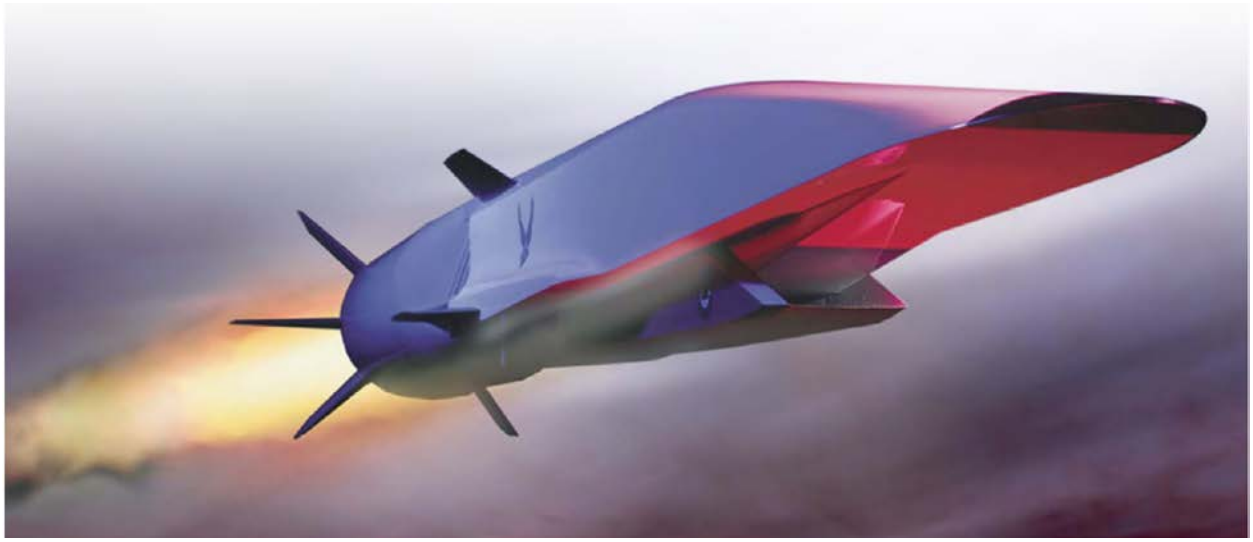
Pursue Multidisciplinary Solutions to Deliver Strategic Capabilities

The transformational component will focus on advancing technology solutions along the following five **strategic capabilities** to move the Air Force from a current force challenged by increasingly sophisticated adversaries to a future force that dominates time, space, and complexity in future conflict:

1. Global Persistent Awareness
2. Resilient Information Sharing
3. Rapid, Effective Decision-Making
4. Complexity, Unpredictability, and Mass
5. Speed and Reach of Disruption and Lethality

Grounded in the National Defense Strategy's key operational problems, these strategic capabilities were determined through a mission integration analysis leveraging the expertise and insights of Air Force future force strategists, stakeholders from across the Air Force, and leading researchers and technologists across industry, academia, and government.

Foundational to battlespace superiority, these capabilities may have had different names at different times in our warfighting past, but they are timeless in their importance. They are not exhaustive but describe the most pervasive needs underlying different Air Force missions. They focus scientific and technical attention on interdisciplinary military challenges and promote competition among alternative ideas and solutions. They encompass both U.S. offensive capabilities and defenses against enemy capabilities. They apply across domains and to both conventional and nuclear missions. Focusing on these capabilities instead of individual technologies will drive a competitive environment where research competes to develop solutions to the most challenging Air Force problems. The strategic capabilities, technological opportunities, and strategic issues are described next and summarized in Table 1.



Global Persistent Awareness

Goal

Support continuous and timely knowledge of adversaries throughout the operating environment via distributed sensing across all domains.

Global persistent awareness is critical for the Air Force to win in a dynamic battlespace. Warfare is becoming increasingly complex due to contested communications, maneuvering targets, and rapidly changing threats. To achieve information superiority, the Air Force must gather decision-quality intelligence and act on it faster than adversaries can react. The Air Force has developed powerful sensing capabilities, including in space and on unmanned air vehicles. However, these capabilities may become vulnerable in conflicts against increasingly capable and lethal adversaries. Current assets are expensive and sometimes lack persistence. Additionally, the data processing and analysis are human-intensive, lack speed, and are often overwhelmed with raw sensor data.

The Air Force must develop capabilities that provide on-demand awareness of adversary actions anywhere on the globe by securely gathering, processing, and fusing multiple types of trusted data from a large, diverse set of sensors.

Lower-cost sensors integrated on distributed platforms can provide resilience through numbers and redundancy and complement more exquisite sensors on standoff platforms in the air, space, and cyberspace domains.

Research in the cyberspace domain provides intelligence directly from electronic-network data, helps convert raw data into timely and useful information, and extends information beyond object and activity identification to include adversary intent.

Edge computing autonomously analyzes sensor data at the source, accelerates the speed of intelligence processing, and reduces the demand on communications networks. The Joint and Allied Force networks will share processed intelligence to enable rapid decision-making and effective delivery.

Resilient Information Sharing

Goal

Coordinate across all Joint Force assets through assured communications and precise positioning, navigation, and timing information resilient to any denial methods.

The Joint Forces' ability to coordinate actions and combine their effects across multiple domains hinges on rapid and resilient information sharing. While not always highly visible, information sharing underlies much of what the Air Force does. It requires high-performance electronic connectivity to flexibly and reliably link computers and systems, manned and unmanned, of different types and generations. Information sharing also requires that those elements obtain precise data regarding time and position, which underlies navigation and synchronization for military operations. The military's demands on these capabilities exceed the limits of current wireless network technology, even under favorable circumstances. In future conflicts, the challenge will be far beyond any of those encountered in the commercial sector. The Air Force cannot rely on the commercial sector to have ready solutions for electronic warfare, Global Positioning System denial of service, and platform attrition.

The Air Force must pursue new, highly flexible, and resilient battle network technology that moves away from previous generation, hub-and-spoke connectivity toward highly redundant mesh networks where systems of different types can connect flexibly and automatically. Such networks will autonomously share data of different types and classification levels across the Joint and Allied Forces. They will adjust gracefully to degradation and reconfigure and change in spectrum, as needed, to maintain connectivity.

Enabling research will include software-defined systems, real-time spectrum awareness, interference detection and compensation, dynamic topology management, encryption, and quantum methods for data security. More robust satellite-based services and new position, navigation, and timing methods based on quantum science, vision-based methods, and other mechanisms must be developed.

Information technology and networking must become pervasive strengths of Air Force research. The Air Force must also effectively leverage the vast capabilities and investments that exist in the commercial sector and combine them with Air Force-specific research to solve these complex challenges.

Rapid, Effective Decision-Making

Goal

Increase the speed of battlespace understanding and decision-making to act faster than any adversary.

Increasing complexity and speed of the battlespace means that the demands on combat decision-makers are outstripping the cognitive capacity of the unaided human. From the cockpit to the headquarters, supporting technology is increasingly vital to process information, separate what is important from what is not, and present it in ways that can be quickly understood and acted upon. As adversaries upgrade their technology, staying ahead in the continuous race for faster and better decision-making will enable warfighting success.

Automation is especially important in electronic and cyberwarfare where contests occur at far-beyond-human speeds. Where possible, automation can assist electronic warfare, cybersystems, and other means to hinder the adversary's decision-making by introducing uncertainty.

Artificial intelligence and predictive analytics are essential to this effort. As the Air Force builds this new core competency, it will need to partner with the commercial sector. To realize the potential of artificial intelligence, the Air Force scientific and technical enterprise must push well beyond developed commercial applications in overcoming major challenges to effective military employment. These include unpredictable and uncertain physical environments, noisy and unstructured data from dissimilar sources, limited training data for machine learning, and the high levels of trust required to support lethal combat operations. Human effectiveness research in cognitive science, data presentation, and human-machine interfaces is also vital to optimize human-machine teaming performance.

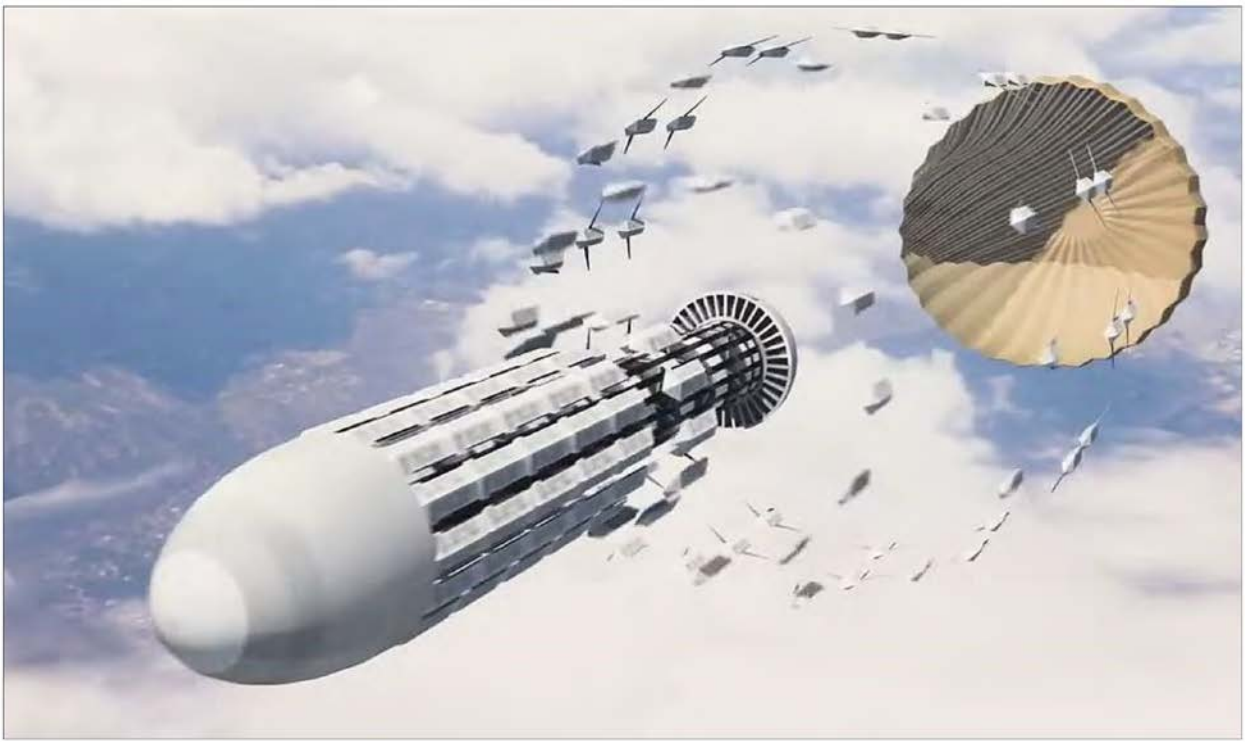
Complexity, Unpredictability, and Mass

Goal

Overwhelm adversaries with complexity, unpredictability, and numbers through a collaborative and autonomous network of systems and effects.

The current force structure relies on relatively small numbers of very valuable assets designed to penetrate highly contested operating environments and sustain operations at forward bases. This creates vulnerabilities for U.S. forces and limits the courses of action available to U.S. warfighters in complex and unpredictable battlespaces. To become more agile, the Air Force must augment its high-end platforms with larger numbers of inexpensive, low-end systems. Swarms of low-cost, autonomous air and space systems can provide adaptability, rapid upgradability, and the capacity to absorb losses that manned systems cannot. By leveraging advances in artificial intelligence, low-cost sensors, and networked communications, low-end systems can restore the agility to attack adversary weaknesses in unexpected ways by exploiting numbers and complexity.

Progress will rely heavily on a wide range of robotics and autonomy technologies, along with sensors and wireless communications. The growing autonomous vehicle market provides an industrial and applied research base that the Air Force can leverage, but military research is needed well beyond what can be expected from the commercial sector. Multidisciplinary efforts are needed to combine research across low-cost platforms, agile digital and additive manufacturing, modular component and material technologies, autonomous system algorithms, and risk-based certification. Methods are needed to control large numbers of autonomous systems coordinated with traditional manned assets. Artificial intelligence advances are needed to achieve high levels of intelligence in small, embedded systems and execute complex missions with trust.



Speed and Reach of Disruption and Lethality

Goal

Rapidly disrupt and neutralize dynamic and mobile targets using new methods to attack with speed and global reach.

Future adversaries will contest access to all warfighting domains—air, land, sea, space, and cyberspace. The Air Force must field a combination of weapons and effects with greater speed and reach. This will include advanced penetrating kinetic weapons combined with new effects from the electromagnetic spectrum and the space and cyberspace domains to create new offensive and defensive options. The Air Force must operate above the speed and beyond the range of its potential adversaries.

Many technologies offer potential. These will advance in a program that includes competitive prototyping and experimentation to assess relative advantages and applications. Like current supersonics, hypersonics has the potential to become a pervasive capability to engage time-critical, heavily-defended, and high-value targets. Advanced smart munitions and unmanned aerial vehicles can penetrate adversary defenses through numbers, stealth, agility, and maneuver. Research in microwave and laser-directed energy systems will pursue offensive and defensive weapons with deep magazines engaging at the speed of light. Cyberoperations, electronic warfare, and artificial intelligence will be combined to degrade and defeat adversary threats and provide access to contested environments, outpacing even the fastest kinetic weapons with tremendous reach.

Table 1. Technological Opportunities and Challenges Within the Five Strategic Capabilities

Strategic Capability	Technological Opportunity	Strategic Challenges
Global Persistent Awareness	• Distributed, multimodal sensing • New sensing modalities: laser and multistatic radar, hyperspectral sensing, and quantum field sensing • Small satellites and low-cost launch • Cyberintelligence, surveillance, and reconnaissance • Enabling microelectronics, photonics, and materials	• Persistence and access through distributed concepts • Expanding the modalities of sensing to capture all observables • Integrated multidomain sensing and information exploitation
Resilient Information Sharing	• Software-defined, agile systems with real-time spectrum awareness • Mesh networking and topology management • Distributed ledgers and robust encryption • Alternative navigation: vision-based, celestial, and magnetic • Quantum science: cold-atom accelerometers, atomic clocks, and quantum entanglement	• Backbone of collaborative autonomous systems • Move from platform-centric data links to resilient, networked communications architecture • Provide self-contained, precise positioning, navigation, and timing resilient to any jamming

Table 1. Technological Opportunities and Challenges Within the Five Strategic Capabilities (Continued)

Strategic Capability	Technological Opportunity	Strategic Challenges
Rapid, Effective Decision-Making	• Artificial intelligence: machine learning and machine-based reasoning • Predictive data analytics • Data fusion and visualization • Autonomous electronic and cyberwarfare agents • Cognitive integration and human-machine teaming	• Increased autonomy in tactical-to-strategic environments • High level of trust required for lethal combat application • Overcoming unpredictability and uncertainty in combat • Organic, artificial intelligence platform for broad application
Complexity, Unpredictability, and Mass	• Low-cost air and space platforms • Agile digital and additive manufacturing • Collaborative autonomy and swarming • Risk-based certification • Multidomain command and control	• Shift to large numbers of collaborative systems providing synergistic, multidomain effects • Need heterogeneous mix of capable, trustworthy, autonomous systems
Speed and Reach of Disruption and Lethality	• Hypersonic flight: scramjet propulsion, high-temperature materials, controls, and experimentation • Low-cost, networked cruise missiles and smart munitions • Microwave and laser-directed energy • Cyberwarfare	• Mature, affordable hypersonics into a pervasive capability • Penetrating weapons with long range, numbers, stealth, and maneuver • Integrated cyberoperations, electronic warfare, and artificial intelligence • Sustained experimentation

"Successful science and technology initiatives may lead to operational prototypes that will be evaluated outside the standard acquisition process in order to develop successful technologies more quickly, while also ensuring that unsuccessful efforts are avoided before consuming scarce funding." – 2019 Missile Defense Review

Advance Future Force Concepts With Vanguard Programs

The transformational scientific and technical component envisions, matures, and demonstrates the science and technology required to enable new warfighting concepts providing leap-ahead capabilities. Guided by strategic capabilities, this component will include a focused set of research programs called **vanguards**. Vanguard programs will advance emerging weapon systems and warfighting concepts through prototyping and experimentation.

Vanguard programs will be limited in time and scope to achieve focus and urgency. While emphasizing advanced technology (BA3), they can synergize applied research (BA2), selected basic research (BA1), and experimentation and prototyping (BA4) to drive forward innovative capabilities. Vanguards are a return to our roots and the early years of post-World War II innovation in air power. Drawing on a legacy of past successes like X-planes, the Century Series aircraft, early imaging CORONA satellites, and stealth, the Air Force will advance concepts rapidly and build force structure when required.

Vanguard programs aim for significant technical achievements, not only of component technologies but also integrated systems and systems-of-systems that demonstrate the viability of leap-ahead capabilities to warfighters (see Figure 2). High risk by design, their goal answers specific questions and informs future decisions by including the direction of future acquisition programs and identifying gaps where more research is still needed. Key elements include warfighter interest and participation and engagement of future force designers.

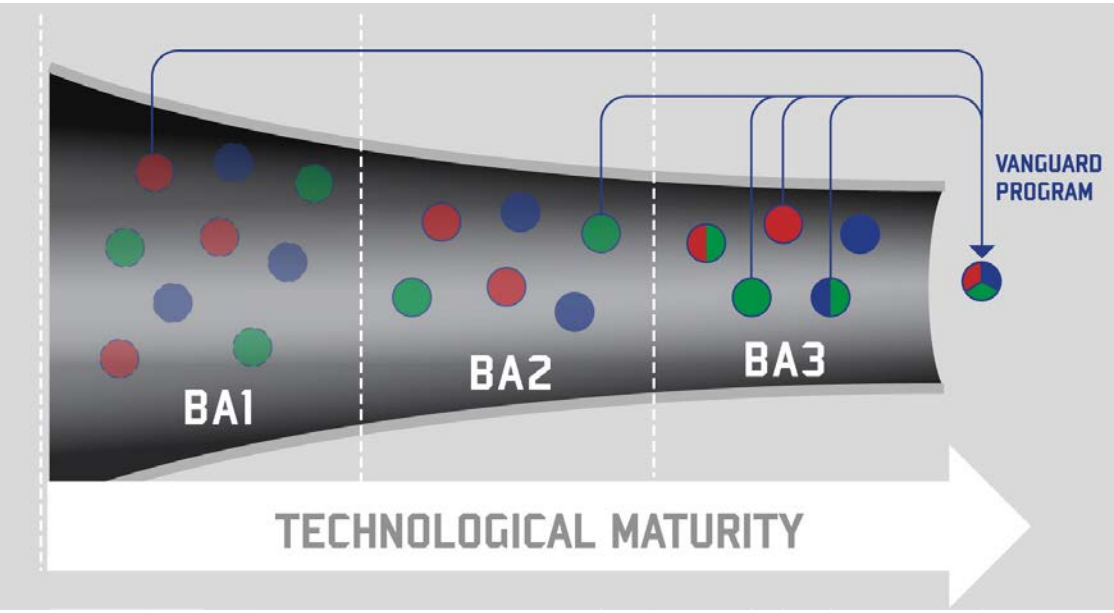


Figure 2. Vanguard Programs Integrate Science and Technology Advances to Demonstrate Potentially Transformational New Military Technologies and Operational Concepts.

A critical skill to build in the Air Force will be the ability to reimagine potential warfighting concepts enabled by these vanguard programs. It is an ability akin to product management in commercial industry. A product manager uses technical expertise and deep understanding of market needs and pulls a vision together for enabling a new product by assembling existing and evolving technologies. Building a cadre of skilled Air Force experts who can merge technical and warfighting expertise is essential to enabling new warfighting concepts.

Construct Competitive and Cross-Disciplinary Management

The new transformational science and technology component will be managed independently from the existing technical discipline-oriented structure. An enterprise-level, cross-organization construct will support the impartiality needed to promote solution-oriented thinking and free competition for resources.

Portfolio managers (or management teams) will chart the course for each strategic capability, manage execution of each vanguard program, and set the competitive environment to identify, select, and manage the research activities. They will also influence supportive efforts in the enabling and enduring component, both within and external to the Air Force. They will use horizon scanning and modeling, simulation, and analysis to guide investment decisions, create technology roadmaps, and track technology maturation, opportunities, and gaps.

The Air Force and other government research organizations, industry, and academia will compete for proposals for the new vanguard programs. Selection will be based on defined criteria emphasizing potential operational relevance and scientific quality.

Develop the Future Force Through Sustained Collaboration

> *"We must anticipate the implications of new technologies on the battlefield, rigorously define the military problems anticipated in future conflict, and foster a culture of experimentation and calculated risk-taking. We must anticipate how competitors and adversaries will employ new operational concepts and technologies to attempt to defeat us, while developing operational concepts to sharpen our competitive advantages and enhance our lethality." – 2018 National Defense Strategy*

Adopting scientific and technical advances rapidly into transformational warfighting capabilities requires collaborative development across doctrine, organization, training, materiel, leadership, personnel, facilities, and policy. These demands sustain an effective collaboration between Air Force scientific and technical activities, future-force developers, and operational stakeholders throughout the major commands.

The core of this collaboration is a closer relationship between the Air Force scientific and technical enterprise and the Air Force Warfighting Integration Capability (AFWIC) to define the transformational science and technology component, maintain correlation with future force design, and effectively leverage results.

The Air Force will strengthen collaboration between the scientific and technical enterprise and future-force development through multiple efforts. AFWIC will establish a senior scientist position and assign additional scientists and engineers on a rotating basis to advise in future-force design efforts.

Likewise, AFWIC will participate in technology prototyping and experimentation events to provide practical feedback on emerging technologies and operational concepts. The scientific and technical enterprise and AFWIC will cosponsor events, such as future-concept modeling and simulation, to inform decision-makers on future technologies and force design.

Ultimately, the interactions will develop and formalize a stronger corporate means to coordinate planning and budgeting activities across the Air Force, from BA1 to BA7, and insert new transformational capabilities into the future force.

"The Department's management structure and processes are not written in stone; they are a means to an end—empowering the warfighter with the knowledge, equipment, and support systems to fight and win. Department leaders will adapt their organizational structures to best support the Joint Force. If current structures hinder substantial increases in lethality or performance, it is expected that Service secretaries and Agency heads will consolidate, eliminate, or restructure as needed." – 2018 National Defense Strategy

OBJECTIVE II: REFORM THE WAY SCIENCE AND TECHNOLOGY IS LED AND MANAGED

Technological innovation, and the military's operational innovation that comes with it, is a primary determinant of Air Force warfighting advantage. Yet the voice of Air Force science and technology within the Air Force's strategic planning and investment decision-making processes is weak.

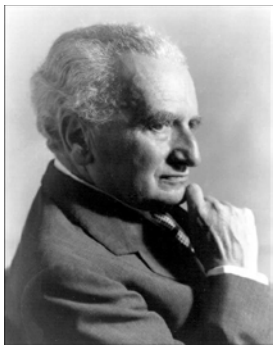
No senior individual has primary responsibility for Air Force science and technology. Its roles and responsibilities disperse within different offices of the Air Force Secretariat, the Air Staff, and the Air Force Materiel Command. The heads of Air Force major commands outrank and overrule the most senior scientific and technical leaders, shifting the focus of scientific and technical resources toward nearer term priorities. This lack of a coherent, strong voice for science and technology lies at the core of the imbalance between science and technology that supports existing needs and concepts and science and technology that advances transformational warfighting concepts that can deliver substantial leaps in dominating, time, space, and complexity. While mechanisms such as the Capability Development Council have aimed to address parts of this gap, more must be done.

Establish an Air Force Chief Technology Officer

Leading technology companies closely align and manage their technology investments as a core part of their strategic decision-making process. Almost always, it is the company's Chief Technology Officer guiding these investment decisions. The Air Force may need an authority, in a role analogous to a large company's Chief Technology Officer, to oversee the science and technology portfolio and champion the needs of long-range, disruptive new capability development.

A Chief Technology Officer would provide a strong voice within Air Force Headquarters and could prioritize and coordinate science and technology across the Service to support the mission, from early-stage research, through developing new concepts, through experimenting and prototyping, to transitioning mature technologies into the Air Force acquisition system. A unified voice at a senior level in the Service could ensure that technology investments produce transformational new capabilities and inform policy and doctrine to shape the missions ahead.

A Chief Technology Officer would also nurture the Air Force's scientific community and ensure effective workforce development for civilian and military scientists and engineers.



"The men in charge of the future Air Forces should always remember that problems never have final or universal solutions, and only a constant inquisitive attitude toward science and a ceaseless and swift adaptation to new developments can maintain the security of this nation through world air supremacy."

— Dr. Theodore Von Karman to General Hap Arnold in the preface of *Toward New Horizons*, 15 December 1945

Establish the Chief Technology Officer's Authorities and Responsibilities

Prioritizing, planning, and budgeting Air Force scientific and technical activities is a complicated, constantly-evolving endeavor that requires input from senior Air Force leadership, major commands, and acquisition centers. It must balance short-, mid-, and long-term needs. The process involves a complex set of stakeholders, forums, and documents. Currently, no one clear, singular voice represents the scientific and technical enterprise in this process. While the current process works, a Chief Technology Officer could improve and accelerate the process through the following:

- Coherent, focused leadership of transformational science and technology including strategic capabilities and vanguard programs.
- Better integration of needs across the range of stakeholders to align common interests and support the formulation of interconnected, cross-domain solutions.
- A stronger, centralized authority to unify strategic direction and sustain its focus within the planning, programming, budgeting, and execution process and in developing the science and technology input for the Air Force budget.
- Greater engagement of the scientific and technical enterprise to provide input and feedback on developing new operational concepts to meet the threats and challenges of the future Air Force.

A Chief Technology Officer would deliver these strategic improvements in planning, executing, leveraging, and overseeing science and technology using the following authorities and responsibilities.

Lead Strategic Planning at Headquarters

- Be the authoritative voice of science and technology for developing and implementing future warfighting concepts by AFWIC and other Air Force organizations responsible for long-term strategic planning. Ensure that the scientific and technical portfolio aligns to produce technology enabling long-term mission concepts and capabilities developed by AFWIC. Communicate scientific and technical advances that could inform the development of these mission concepts and capabilities.
- Champion and implement policy and authorities enabling rapid and agile resourcing, hiring, prototyping, and experimenting capabilities within Air Force science and technology to achieve necessary flexibility for addressing the challenging future environment.
- Serve as the central voice for the scientific and technical enterprise in the planning, programing, and budgeting process.

Integrate With the Major Commands and Acquisition Authorities

- Integrate and prioritize scientific and technical investments to produce a balanced and optimized portfolio to meet the present and future scientific and technical needs of the major commands and acquisition centers. Ensure coordination of priorities with the Headquarters staff, the Assistant Secretary of the Air Force for Acquisition, and the Secretary of the Air Force.
- Develop policy, strategy, and resource allocations for science and technology across the Air Force from BA1 to BA4.
- Oversee and approve the strategic capabilities driving the transformational element of the scientific and technical portfolio and manage the process to select vanguard programs.

Manage the Air Force's Scientific and Technical Portfolio

- Serve as the individual with direct oversight of the Air Force Research Laboratory.
- Ensure the scientific and technical enterprise portfolio is organized and resourced in dollars and manpower to appropriately lead, leverage, or watch across the technical disciplines required to support the needs of the Air Force's functions and capabilities.
- Ensure that the acquisition, finance, and personnel tools and processes for the scientific and technical enterprise uses current authorities and expand those authorities to increase speed and efficiency of executing research within the portfolio.

Given science and technology investments must now be made in competing areas, both inside and outside of the Air Force Research Laboratory, science and technology needs a strong voice at a senior level within the Air Force. Creating a Chief Technology Officer role could enhance focus on the science and technology required to secure the technical advantage of the Air Force for future decades.

The creation of a Chief Technology Officer may require the approval of Congress, potentially including a statutory change of the responsibilities of Assistant Secretaries of the Air Force. Details regarding the authorities and responsibilities of the Chief Technology Officer and his or her relationship to existing authorities and responsibilities across the Headquarters Air Force staff, major commands, and acquisition centers will be determined during the implementation phase of this Strategy.

"Recruiting, developing, and retaining a high-quality military and civilian workforce is essential for warfighting success. Cultivating a lethal, agile force requires more than just new technologies and posture changes; it depends on the ability of our warfighters and the Department workforce to integrate new capabilities, adapt warfighting approaches and change business practices to achieve mission success. The creativity and talent of the American warfighter is our greatest enduring strength, and one we do not take for granted." – 2018 National Defense Strategy

OBJECTIVE III: DEEPEN AND EXPAND THE SCIENTIFIC AND TECHNICAL ENTERPRISE

As the center of mass of technological innovation shifts away from the Defense Department, it is more important than ever for the Air Force to renew its focus on scientific and technical talent. This Strategy focuses internally on organic scientific and technical expertise and externally on the expansive partnerships necessary to effectively leverage global innovation.

Air Force technological superiority has always relied on a national and international enterprise, including government laboratories and a synergistic network of universities, industry, and allies. As allies and adversaries become more technologically capable, these relationships will become even more important. Home to much of the organic expertise, the Air Force Research Laboratory plays a vital role in translating and transitioning innovation fostered by these partnerships into Air Force capabilities. The Air Force must maintain strong internal scientific and technical expertise and deepen external partnerships.

Engage and Support a Technical and Driven Workforce

The Air Force's scientific and technical workforce is foundational to maintaining and accelerating technological advantage. The Air Force aims to attract, develop, and retain exceptional talent and create a culture of innovation and risk-taking conducive to driving research from basic science to transformational military capability.

Enhance Access to Top National and Global Talent

The Air Force will enhance recruiting to ensure a strong pipeline of top scientific and technical talent. Specific objectives to bolster recruiting include the following:

- Strengthen, streamline, and augment graduate student, postdoctoral researcher, and internship programs for U.S. and allied nation engineers and scientists.
- Significantly expand competition for and engagement of university-based Air Force research through competitive grant awards, including the funding of doctoral students, summer faculty research experiences, and sabbaticals at Air Force laboratories in order to connect the best scientific talent outside of the Air Force to important Air Force problems.
- Evaluate service pilots similar to the U.S. Army Research Laboratory's Open Campus, potentially expanding engagement and formally integrating them into Air Force procedures.

- Expand active recruiting efforts to expand a pipeline of talent from diverse educational backgrounds. Take advantage of data analytics to identify the best-in-field.
- Leverage other Service/Agency recruiting initiatives and establish flexibilities to exchange talent with other U.S. government organizations to increase collaboration and the Air Force's technical base.

Advance Innovative Workforce Development

> *"Developing leaders who are competent in national-level decision-making requires broad revision of talent management among the Armed Services, including fellowships, civilian education, and assignments that increase understanding of interagency decision-making processes, as well as alliances and coalitions." – 2018 National Defense Strategy*

After recruiting top talent, the Air Force must retain it. The Air Force will develop and support highly motivated individuals within an engaging work environment that encourages smart risk-taking and creates exciting, professional development opportunities. Objectives include the following:

- Implement new incentives, and competition, to encourage appropriate risk-taking and reduce risk aversion. Empower leaders to reward informed risk-accepting behavior, even if the outcome is not always successful. Enhance the ability to share lessons learned across the organization.
- Maximize flexible workforce authorities that allow pathways to expand expertise, such as sabbaticals with academia, internships and training with industry, and entrepreneurial sabbaticals, creating pilot programs if needed.
- Increase training and developmental assignments across the Air Force and the Department of Defense.
- Establish dedicated resources to facilitate assignment opportunities, such as tuition reimbursement, relocation or travel cost reimbursement for rotational assignments away from home stations, and temporary hiring to backfill gaps.
- Implement a pilot program to embed scientists and engineers in an operational environment that expands their understanding of the warfighter's issues while minimizing the need for special clearances where possible.

Create a Strong Pipeline of Technology-Proficient Military Airmen

The Air Force's history illustrates the importance of technically proficient, visionary military leaders in moving new technologies and technology-driven warfighting concepts into operations. Objectives to foster the development of these leaders include the following:

- Purposefully manage the military science, technology, engineering, and mathematical sciences career fields. Ensure that the technical expertise of military members, like their civilian counterparts, is fully leveraged to drive Air Force science and technology toward transformational Air Force capabilities.

- Support opportunities for the scientific and technical military workforce to broaden its technical expertise and expand its warfighter perspective to include positions at other Service/Agency scientific and technical organizations.
- Identify a set of General Officer billets across the Air Force that require advanced science, technology, engineering, or mathematics degrees. Promote officers with the right scientific and technical education, training, and experience to fill these important leadership roles.

Exercise Granted Authorities to Support Agile Workforce Practices

Congress and the Department of Defense established new authorities to enable agile science and technology workforce practices. However, implementation has been complicated by requirements levied by higher headquarters that may not themselves be affected by these science and technology-specific authorities. To address this, the Air Force will:

- Eliminate policies that minimize or delay adopting granted authorities or suppress the intention of the special authority at all levels within the Air Force.
- Establish new human capital procedures to implement granted authorities specific to the science and technology enterprise. Exercise flexible hiring to include term and temporary appointments, temporary promotions, contracted employees, student programs, partnership intermediary agreements, and other applicable authorities.
- Embrace the various methods available to hire into and manage the scientific and technical enterprise. Using these authorities must become routine and not require significant leadership oversight to ensure they happen. Approval authority will be pushed down to the lowest appropriate level of leadership.

Drive Innovation Through Partnerships

"The Department's technological advantage depends on a healthy and secure national security innovation base that includes both traditional and non-traditional defense partners." – 2018 National Defense Strategy

The Air Force will look widely for the best scientific and technical talent and research as innovation arises from new perspectives. The Air Force will harvest new perspectives by placing personnel in hotspot locations as well as making it easy for new talent and research to find Air Force partners. Partnerships will expand and strengthen to draw technology out of government, university, and industry laboratories and mature it into transformational operational capabilities. In particular, this includes better leveraging promising basic research discoveries by forming deeper university partnerships in applied research to move these innovations further toward transformational Air Force impact.

Expand the Air Force's Scientific Presence

More Air Force-relevant research is happening in the private sector beyond the Air Force's current locations and often far from our bases. To be more active and engaged where this research occurs, the Air Force will:

- Establish visiting professor or research faculty positions for Air Force researchers in research universities.
- Leverage and expand upon the Army Research Laboratory's Open Campus concept, enabling Air Force scientists and engineers to meet and work side-by-side with visiting scientists in collaborative facilities.

Create a More Visible Air Force Science and Technology Enterprise Front Door

Many potential partners who want to interact with the Air Force have difficulty in navigating its structure. The Air Force will relieve this burden by creating a convenient virtual "front door" to rapidly connect with Air Force experts and opportunities. We will:

- Provide a service to connect industry, individuals, universities, and government research centers with experts inside the Air Force science and technology enterprise. Encourage deeper dialogue between the Air Force science and technology enterprise and new connections to identify novel partnerships and potential opportunities for innovation.
- Create, manage, review, and update partnership mechanisms and processes focused on efficiency.
- Increase idea solicitation from all sources by regularly enabling outreach activities to help build expertise and streamline the idea solicitation process.

Cultivate Partnerships and Increase Technology Transition Opportunities

The Air Force will also increase focus on and strengthen relationships with other government laboratories, universities, industry, and allies. The driving pace of technology and competition for leading-edge talent demands the Air Force leverage partnerships to ensure agile pursuit of the most impactful research. Integrating efforts across the research spectrum from basic, to applied, to vanguard programs will help drive technology transitions and transformational capabilities.

The Air Force will strengthen partnerships to increase technology transition through the following:

- Expand constructs such as the Centers of Excellence to capitalize on basic research successes and provide opportunities for deeper university engagement at the applied research level where the Air Force can gain technological advantage.
- Expand nontraditional contracting to access and leverage commercially-driven innovation in private sector companies relevant to the Air Force mission.
- Establish a stronger connection between the Air Force basic research program, executed by the Air Force Office of Scientific Research, and the Air Force Research Laboratory technology directorates.

- Maintain a high percentage of research sponsored by the Air Force Office of Scientific Research at universities in order to connect the Air Force to the broader scientific community and ensure access to the most competitive research laboratories.
- Identify and support opportunities for multi-Service or multi-Agency funded research initiatives to create new synergies and leverage resources and technical talent.
- Identify and support opportunities for the scientific and technical civilian and military workforce to expand its technical network and research partnerships through temporary assignments at other scientific and technical organizations.

CALL TO ACTION

The Science and Technology Strategy of the 1970s was about conferring unprecedented force multiplication advantage to our military. While force multiplication is still a key component of our technology advantage, the vision of this Strategy is an Air Force that dominates time, space, and complexity in future conflict across all operating domains to project power and defend the homeland. This means that it operates at an unmatched pace of action, achieves unparalleled reach of awareness and effect, and harnesses the power of complexity to enhance resilience in contested environments and impart overwhelming confusion on adversaries. Air Force science and technology will drive the transformational operational capabilities that will make this vision a reality.

This Strategy secures the Air Force's continued technological advantage over rapidly developing state competitors in 2030 and beyond in support of the National Defense Strategy. It focuses research in multidisciplinary directions to enable that advantage and paves the way to convert new technologies into transformational warfighting concepts. It makes important changes to science and technology management at the headquarters and laboratory levels to more effectively develop those concepts and support their transition into the future force.

Through sustained commitment to implementing the goals of this Strategy, the Air Force will position itself to continue to deliver disruptive innovations to the Joint warfighter to ensure the nation's defense.

UNITED STATES
AIR FORCE

TIME – SPACE – COMPLEXITY

SCIENCE AND TECHNOLOGY STRATEGY

STRENGTHENING USAF SCIENCE AND TECHNOLOGY FOR 2030 AND BEYOND

APRIL 2019