



Department of the Air Force

Report to Congressional Committees

The Department of the Air Force In 2050

December 2024

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SECRETARY OF THE AIR FORCE
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The Department of the Air Force in 2050

Thank you for this opportunity to present a picture of the Department of the Air Force (DAF) that the nation is likely to need in 2050. The report paints a broad description of the national security environment in 2050, expected technology advances, and the resulting composition of the Air Force and Space Force in the 2050 timeframe. The report relies on a reasonable set of assumptions and provides some discussion of excursions from those assumptions.

We were unable to create with any confidence either a road map of the path from 2025 to 2050 or a detailed quantitative description of the order of battle for the Space Force and Air Force in that timeframe. The uncertainties are simply too great. As the introduction to this report states, there is enormous uncertainty about the events that will transpire over the next 25 years, about threats we can expect, about the technologies that will be available, about the budget decisions that will be made, and about the degree of persistent institutional innovation and change that will be supported within the DAF. Funding and the willingness to make trade-offs between current, near-term, and longer-term investments will be central to the achievable pace of change. There are two, widely disparate, bookends of the future that are quite plausible.

In one plausible scenario, constraints inside and outside the DAF's control stymie efforts to modernize at scale. Among these constraints are: budgets for the DAF that remain flat due to a combination of overall Department of Defense (DoD) constraints and lack of willingness or political will to shift resources within the DoD; the resistance to any combination of the retirement of aging and obsolete weapons systems; the reduction of overseas deployments; or the closure of excess infrastructure. These constraints, if coupled with institutional cultural resistance to innovation, will lead to a 2050 force that looks very much like the current force, with some degree of modernization through replacement of existing systems with similar capabilities.

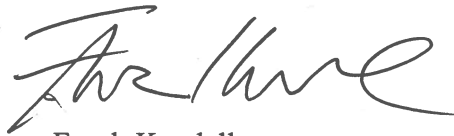
In the second plausible scenario there is an enduring political consensus that the pacing challenge of China demands a strong national response which emphasizes transformative modernization of the Air Force and Space Force. In this scenario, strong Executive branch and Congressional leadership, in partnership with leaders in the Military Departments and Services provides both adequate resources as well as technical and operationally innovative leadership that overcomes cultural and institutional inertia to successfully focus on maintaining US military superiority in the space, air, and cyber domains.

As you can well imagine these scenarios lead to very different results in 2050. This report assumes a scenario within these bookends, but closer to the more optimistic second scenario and adequate to meet anticipated threats. For the last few years, the DAF has worked to execute this scenario. We have identified innovative cost-effective investments that exploit emerging technology and address the pacing challenge. With strong support

from the Secretary of Defense, the President, and the Congress we have been able to initiate many of the needed programs that we identified as essential to addressing our operational imperatives. We have also made or initiated the structural and institutional changes needed to reoptimize the DAF for great power competition.

Whether or not this work continues and fulfills the vision described in this report for 2050 will be in the hands of future Administrations and the Congress.

Sincerely,

A handwritten signature in black ink, appearing to read "Frank Kendall". The signature is fluid and cursive, with a large initial "F" and a long, sweeping tail.

Frank Kendall
Secretary of the Air Force



Executive Summary

This report lays out a vision of what the Department of the Air Force (DAF), which is comprised of the nation's Air Force and Space Force, should look like in 2050. This report does not attempt to build a plan describing how that vision can be achieved using 2025 as a starting point. Rather, it provides as clear a picture as the distance in time permits of the future military capabilities the nation is most likely to desire in that time frame. A great deal of change can occur in 25 years. There is enormous uncertainty about the events that will transpire over the next 25 years, about the technologies that will be available by then, and about the threats to national security that will exist. The report addresses this uncertainty and assesses the elements that can be anticipated with some degree of confidence, and those for which major deviations are possible and should be considered. The most significant assumption we make is that threats to our national security will still exist, and those threats will include both conventional and nuclear adversaries with the capacity and the will to challenge the interests, the values, and even the existence of the United States and its allies. In 2050, the United States will still need an Air Force and a Space Force, but they may look very different from today's Services.

China will remain the pacing challenge to the United States and to democratic powers in general, especially, but not solely, in the Indo-Pacific region. Recognizing this reality, the DAF has spent considerable effort in reoptimizing the Department for great power competition. These efforts were designed to create an enterprise-wide competitive ecosystem, postured for long-term strategic competition. They included: establishing a Space Force Futures Command and an Air Force Integrated Capabilities Command; creating deployable Air Force operational wings; standing up new Air Force acquisition and technology Systems Centers; reshaping the education of Air Force Airmen and Space Force Guardians; creating a core of more technical professionals, including by reestablishing Air Force warrant officers for cyber and information technology; and, in the DAF Secretariat, creating organizations to perform strategic program assessments, guide modernization, and conduct competitive activities. This framework will evolve through 2050 but should not fundamentally change.

Report

The 2050 National Security Context

International Competition

The assumption is that something like the current divisions of power and interests will endure; though changes may occur, they will not fundamentally change the relationships and competitive interests of major powers and international associations. China will continue to grow its military capabilities with the intent of challenging U.S. dominance in all domains. By 2050, China will be in a position to challenge the United States and its allies globally as well as regionally in the Indo-Pacific area.

Major Powers

By 2050 it is all but certain that Xi Jin Ping and Vladimir Putin will be out of power. There is a wildcard possibility that new leadership will choose fundamentally different directions for China or Russia, but the baseline assumption will be that both states remain autocratic and consider the United States and other democracies to represent rival powers. As Secretary of State Antony Blinken has indicated, an alignment that includes China, Russia, North Korea, and Iran against the democratic powers is a possibility and should be deterred if possible. Conversely, increasing concerns about China's aggressive intentions could stimulate a multi-lateral alliance or alliances in the Indo-Pacific region. If these developments did occur, they would have impacts on size and distribution of capabilities in the DAF of 2050, but not on the nature of the Department nor on the types of organizations, training, and equipment of the Air Force and Space Force.

China's growth will continue, but at a reduced rate as demographics and authoritarian economic mismanagement influence productivity. China will continue to grow its nuclear forces to levels comparable to those of the United States and Russia. China will also continue the expansion and reach of its military and its attempt to influence global events. China is likely to acquire some additional international basing, but it will avoid the large-scale global deployments that characterize the current posture of the United States. The Taiwan "issue" may or may not be resolved, however, if it has been, other points of friction between China and neighboring states will still exist. China's reliance on a combination of cutting-edge technology, innovative operational concepts, operationalized use of the space domain, emphasis on information dominance, and, increasingly, long-range precision weapons of all types will continue.

Russia will remain hostile, but its ambitions will be limited by the weakness of its economy. If clean energy technology matures before 2050, Russia's dependence on extractive fossil fuel exports will be a limiting factor in its ambitions. Russia and China are likely to remain at least opportunistically aligned, with Russia as the weak partner in the relationship. Russia will continue its high reliance on nuclear weapons for security against the West and will field some combination of the exotic weapons it has in development today, even potentially stationing nuclear anti-satellite weapons in space. Any stationing of nuclear weapons in space would be highly destabilizing; this is not a baseline assumption for this report, but it is a real possibility. Russia will also attempt to rebuild its conventional forces following the termination of the Ukraine war, but it will not be able to rival the conventional forces available to NATO due to its economic constraints.

A mutual defense pact between Russia and China is possible but is not considered a baseline assumption. Neither Russia nor China will want to be obligated to enter a conflict the other initiates.

Arms control agreements will not limit the nuclear or conventional forces of the major powers. Wildcards are plausible. For example, some set of events, such as a nuclear detonation or regional exchange, may motivate a renewed impetus for arms control, but the difficulty in reaching a three-party agreement and China's lack of interest in arms control

make it unlikely. If there is a renewed interest in arms control, it will not lead to the elimination of nuclear weapons. The “nuclear club” will not shrink, and there is a good chance that there will be additional members by 2050, motivated by local threats and the perception that nuclear weapons provide deterrents against others who have joined the nuclear club. If the perceived value and reliability of the nuclear security umbrella provided by the United States to our allies diminishes, proliferation will be more likely to occur.

Other Powers

There may be some changes in alignment on the margins but, generally, the current alignments of states will still exist. The U.S. system of alliances will continue. In the Indo-Pacific, if China’s pattern of aggression continues, there is a reasonable chance of a multi-state defense agreement that would include the United States, Japan, and Australia and perhaps others. China, and to a lesser extent Russia, will try to increase their influence internationally by courting, bribing, or coercing smaller states into their camps. They may have some measure of success, but not one of major significance to the global balance of power. Many states, particularly in the global south, will prefer to remain unaligned. A wild card event could be Chinese aggression, most likely against Taiwan, resulting in a formal defense alliance in the Indo-Pacific in opposition to additional Chinese aggression. This would depend upon how aggressive China becomes and how states in the region react. A global bipolar alignment similar to the Cold War is possible but not considered the most likely course of events due to the extensive involvement of China in the global economy.

Non-State Actors and Instability

Unfortunately, these threats will still be with us in 2050. The religious extremism, tribalism, and criminality that drive non-state groups will still motivate them, and they will use indiscriminate violence against their perceived enemies. Attempts to eliminate this threat will fail. A wildcard event would be another mass casualty attack on the United States itself or an ally, particularly one using a weapon of mass destruction. Just as 9/11 led to two decades of global reaction by the United States, such an event could dramatically alter U.S. military priorities and allocations of resources away from strategic and conventional nation-state threats. The report assumes this will not occur, or, if there is a mass casualty attack, that the United States will of course respond, but not to the extent it ignores all other strategic priorities. Similarly, civil unrest can lead to destabilizing and difficult to predict state collapse as we have seen in Syria and Afghanistan. This report also assumes that an event like this, if it did occur, would not fundamentally affect U.S. strategic priorities.

Climate Change

The effects of climate change will continue to be felt in increasing severity over the next 25 years. Excluding the direct effects of climate change, including drought, severe weather, and rising sea levels, the most significant national security threat may be mass migration to escape the effects of climate change in those regions most severely affected. This is not regarded as a major driver for the Air Force and Space Force of 2050, but it may have a profound impact on U.S. society and priorities for national investment.

Economic Competition

As indicated in the National Security Strategy and National Defense Strategy, economic competition will be the most intense and fundamental area of competition between the United States and China. The American free enterprise system will remain the best economic engine in history; however, in 2050, China will still be a serious economic competitor. This will be the case despite the inefficiencies inherent in an autocratically controlled economic system. China's sheer scale and inherent resources will keep it at a comparable economic level to the United States. China will also continue to employ a variety of state-controlled mechanisms to tilt the playing field in its favor, starting with significant threats to the supply chain as a means of imposing its political will, and including use of infrastructure investments to gain influence, unfair trade practices, intellectual property theft, and manipulation of international standards organizations.

Technological Advances by 2050

Technology has a profound effect on warfare and a number of developments are possible before 2050, including some wildcards that could have a major impact on the character of warfare. This report considers seven areas of technological change for which there is already some evidence of the potential impact, direction of change, and rate of change. Today, the United States is in a race for military technological superiority with China and, to a lesser extent, Russia. There is no indication that this situation in 2050 will be significantly different. The rate and nature of technological change is extremely difficult, if not impossible, to predict, as are the timing and mechanisms that bring technological developments together with military operational concepts and organizational structures to effect meaningful change in how military organizations are structured and equipped for use in operational practice. Often the significance of a new technology is not fully appreciated or grasped until it is employed in combat. Even then, the resistance to change can be severe. This report assumes that the United States recognizes the operational implications of technology emerging today and over the next 25 years and, motivated by the strategic threat posed primarily by China, moves quickly to apply those technologies.

Artificial Intelligence

Artificial intelligence (AI) in this context refers to the use of computerized or digitally-based decision making, decision support, and efficiency. (Autonomy is separate from, but associated with, AI, and will be discussed below.) AI covers a range of technologies that offer to perform functions traditionally performed by humans, but with some combination of much higher speed and accuracy. Examples abound. In some cases, AI technologies are performing and will perform many tasks not possible within the constraints of the human mind. This is an extension of the more traditional features of modern computing, but the extension is by large factors, in some cases by many orders of magnitude. As AI advances, we will either choose to assign more authority to the computer system, much as a supervisor assigning more responsibility to an employee who has improved their performance, or we will fall behind adversaries who adapt more quickly. How much further this technology will progress in the next 25 years is unknown. However, high payoff

military use cases or applications are being explored now and will only expand. Well before 2050, the use of advanced decision and decision support tools will be at the core of a variety of military functions and capabilities. In both the air and space domains, decision dominance will depend on AI technologies. Battle management (BM), the control of forces in planning phases and in dynamic decision-making during execution of military operations, is an obvious application. Using AI to inform planning for the fight and its dynamic execution may be its area of greatest impact. Extraction of target identification and tracking from large multi-sensor databases is another. Areas of conflict that move at speeds vastly exceeding human decision time constants, such as cyber warfare and electronic warfare, are likely to be dominated by AI technologies that assess events happening at unimaginably fast speeds and unimaginably small dimensions. These technologies will be used to make crucial decisions with no possibility of human intervention. Victory or defeat in the air or in space at the human scale is likely to be determined by which combatant has fielded the most advanced AI technology in the areas most crucial to achieving victory.

Autonomy

Autonomy, which is closely related to and dependent on AI, has deep significance for the Air Force and Space Force of 2050, particularly the Air Force. The Space Force already operates highly autonomous systems. We see evidence daily of the increasing use of autonomous platforms or vehicles. The only open questions about autonomy are how fast it will mature and what form it will take. The direction is quite clear at this point. By 2050, we can reasonably expect autonomous vehicle operation to be the norm, in all domains.

Warfare involves the delivery of destructive force to an opposing target set. Human beings have always provided a key component of the military delivery system, until recently. For over one hundred years, air forces have relied on crewed flying machines to deliver destructive mechanisms to within the range at which they can be effective. This is already changing and changing quickly. Increasingly, aircraft and spacecraft fly autonomously, with varying degrees of human control. Commercial airliners today, while still crewed, have high degrees of autonomy. Space systems have always been largely autonomous, and that trend will continue for the foreseeable future. In general, weapons themselves have become “smarter” and more capable of acting without human inputs once they are committed to a target, target class, or engagement area. As Americans, we believe that any autonomous military system must act consistently with our values and not violate the law of armed conflict, but this does not preclude the use of this technology. It does mean, however, that we must act to ensure that any systems we field are reliable, will perform as intended, and do so consistent with our values. Acting consistently with our values will mean that we must work harder to maintain a competitive advantage in this area, both despite, and because of, the fact that our adversaries may not respect these norms and values.

Computing and Sensing

Computing and sensing are core technologies that enable other advances, including AI and autonomy. Moore’s Law, which is an empirical observation not a law, has been reaching the end of its period of applicability for some time. Computing, data storage, and

data transport may continue at the pace of the last two or three decades, or they may slow as the inherent limitations of physics assert themselves. Conversely, a new breakthrough may be achieved. Quantum computing and quantum sensing are in early and varying stages of maturity. Quantum computing could fundamentally alter cryptology. Quantum sensing could negate many, if not all, modern concealment technologies, including stealth technologies. Our assumption is that computing and sensing technologies will continue to advance, but any advances by one major competitor will quickly be replicated and provide only a temporary military advantage.

Long-Range Precision Weapons

The history of warfare is largely about delivering lethal effects at ever increasing range and accuracy. A variety of technologies support this trend, including hypersonic propulsion, smart seekers, and automated target identification and targeting. China's military modernization program has been largely about investments in long-range precision, originally to a few hundred miles and now to over 1,000. Intercontinental precision conventional capabilities have already been demonstrated through the Chinese fractional orbital hypersonic vehicle test. China's massive investment in air-, land-, and sea-launched medium-range systems and systems that reach the so-called second island chain and beyond have already put traditional Air Force systems and operating concepts at risk. We can only expect this trend to continue. In 2050, we should expect to be under the threat of ultra long-range precision weapons at any range and launched from any domain, including space. There will be no sanctuary from these weapons.

Space Technology

A revolution in the cost of both space launch and space systems is well underway. It remains to be seen if commercial ambitions to extract materials from the moon or colonize Mars are realistic, but there is no question that the cost of access to space and the cost of satellite systems have been drastically reduced. This trend will continue. There are also strong indications that proliferated architectures and commercial constellations for communications and continuous earth observation will continue to exist or grow in capability. Commercial developments in space mobility, logistics, and in-space assembly and manufacturing also have the potential to revolutionize the applications of services to, in, and from space. These developments are all creating significant threats to, and opportunities for, the Joint Force that both China and the United States are already exploiting.

Energy

Over the next 25 years, we expect the transition away from fossil fuels will continue, but their use will not be eliminated. A wildcard is the potential for a breakthrough technology, such as a fusion power source, to effectively end the dominance of petroleum and coal as energy sources. Because military operations primarily involve mobile platforms, some form of practical mobile power source with cost-effective energy production and high-energy density will be required. There are a number of possibilities (e.g. hydrogen, electric). The commercial need for more efficient and cleaner energy will be the primary motivator and

source of capital for investment in this area and one can assume that the military will adopt the most attractive technologies for platform energy sources that emerge. Propulsion for weapons (liquid or solid fuels) is more likely to follow an evolutionary, incremental development trajectory through 2050.

Biological Science

This area of technology is a wild card, but worth noting. The ability to manipulate genetic material is real; it exists now and may lead to militarily significant developments over the next 25 years as applications are explored and expanded. However, specific advances with major Air Force and Space Force implications are not predictable with confidence. One area of potential change is increased human performance, through biological manipulation or human-machine cognitive integration. The development of new materials through biologically-based processes also has high potential. Most concerning may be the potential for biological weapons designed for specific targets.

The Character of War in 2050

Overarching Changes

The most significant change for the United States and the DAF is that we now have, and will likely continue to have, a well-resourced, technologically sophisticated, and open-minded potential adversary: the People's Liberation Army or PLA. We have begun to come to grips with the implications of the emergence of a formidable peer competitor, a great power with values antithetical to ours and ambitions at odds with our national interests. Russia may also fit this description in 2050, but without the resources expected of China. The major implication of this likely fact is that the most advanced technologies available will be used to create new and novel operational concepts, organizations, and weapons systems intended to deter and defeat the United States and our allies. We are evolving toward a remote-control war which, by 2050, may be a reality. Success in this type of conflict will require a blend of advanced sensors, other information sources, secure communications, and state of the art AI to support decision making. Fighting this kind of war hinges on space and cyber capabilities. Nothing will ever happen, no matter how sophisticated, without a reasonable chance of being noticed and understood.

Even a largely localized conflict will come to the U.S. homeland, and not only through the possible use of long-range precision kinetic weapons against our territory. Critical military and non-military infrastructure—as well as human cognition itself—will be at risk of kinetic and non-kinetic attack in cyber and information domains. This will affect military operations conducted by the Air Force and Space Force but also have a broader societal impact.

Some of the most visible and predictable areas of military applications of advanced technology development have been discussed above. It is likely these areas of advanced military technology will be manifest through the increasingly widespread use of autonomy and automation, in all domains, but especially in space, in cyberspace, and in the air.

The high vulnerability of fixed sites, including forward air bases, to massive and continuous precision strike is another inescapable change that is already well underway. There will be a general need to distribute and conceal military value so that it is less vulnerable to attack. This will be true in all domains and at all altitudes: space, air, ground, sea, and undersea. The tendency of the United States to rely upon increasingly high-cost exquisite systems in small numbers will have to be reversed. The tendency to make major warfighting platforms self-sufficient and both lethal and survivable independently will be replaced by the need to disaggregate and network capabilities across multiple systems, which in turn, will drive adversary development of systems and weapons designed to deny, destroy or counter disaggregated capabilities. The speed at which future warfare will occur and the complexity of the operations quickly exceeds the limits of human comprehension and interaction to effectively battle manage and command and control forces at scale without some form of human-machine interface and automation. Importantly, any achieved advantage will be transitory; frequent, even continuous, improvements and the ability to react quickly to changes in the threat will have a highly competitive value.

The Space Domain

By 2050, space will be recognized as the decisive domain for almost all military operations. With the reductions in cost of space access and space systems, we can expect the United States, China, and Russia to be engaged in a robust effort to obtain military advantages in the space domain. Allies and partners will have further developed their own military space systems and integration of space acquisition, doctrine, and operations will be necessary to conduct global allied and partner operations that rely on a multitude of space systems. Global presence, continuous earth and atmospheric observation, and high bandwidth communications are all critical enablers for military forces in all domains. Capabilities in each of these areas will improve and proliferate through 2050.

China is already fielding a global warfighting operational space suite of capabilities to enable global force support to include navigation, ISR, targeting, and communications. By 2050, there will be significant numbers of adversary terrestrially-based and space-based weapons that can attack space systems and ready for use with little or no warning. There are reports that Russia may field a counterspace weapon of mass destruction in space. This has not happened yet, and it would be a violation of the Outer Space Treaty to place a weapon of mass destruction in space. The United States will continue to remain compliant with the Outer Space Treaty. China has tested an orbital hypersonic glide vehicle which could further add a dimension of conventional attacks from space. Any such deployments – whether space nuclear detonations or orbital hypersonic glide vehicles – would be highly destabilizing, however there are no significant technical or financial obstacles to this occurring between now and 2050.

Space is a domain that can be continuously observed, making survival challenging and potentially characterized by a strong and destabilizing “first mover advantage.” A wide range of counterspace systems have already been fielded by potential adversaries. Almost a decade ago, during the Obama Administration, the Department of Defense looked at the

question of increasing dependency on space-based systems or walking away from those dependencies due to concerns about survivability. The decision was to increase our use of space, taking into account the foreign threats from and use of space. The Space Force of 2050 will be consistent with that decision, but it will not look anything like our historical collection of space assets. The Space Force of 2050 must be more capable, more survivable, and more integrated than anything that precedes it. This will require a major and transformative investment in the Space Force. The DAF has already begun the transition from reliance on Air Force systems like Airborne Warning and Control System (AWACS) and Joint Surveillance Target Attack Radar System (JSTARS) to space-based surveillance sensors for direct operational support, especially surface and air moving target tracking and targeting.

The space domain in 2050 will be used to provide a range of operational services to the entire Joint and Combined force. These will include missile warning and tracking, nuclear detonation detection, real time targeting, secure communications and battle management, and protection from adversary space systems. Control of space in 2050 will be aggressively contested – it already is. Adversary space systems may include weapons prepositioned in space for terrestrial attack. The United States cannot afford to cede control of space to an adversary and the Joint and Combined Force cannot operate if adversary space systems are allowed to target the Joint Force with impunity. Without resilient space-based services and protection from adversary space systems the Joint Force of 2050 will fail.

The Air Domain

War in the air in 2050 may look very different from its historical precedents. Since its inception, conflict in the air domain has been about the desire to establish control of the air, both defensively in one's own airspace and offensively in an adversary's airspace. Control of the air has been seen as a necessary precursor to operations on the surface of the earth, on land, and at sea. Crewed aircraft—multi-role fighters and bombers operating from relatively secure airbases and able to survive multiple sorties once air superiority was established—have extended strike ranges efficiently against the full range of land and sea targets. The ability to deliver munitions at scale through bombing campaigns with acceptable loss rates has also depended on the ability to achieve control of the air domain, at least temporarily.

By 2050, against the most stressing adversaries, we will have to rewrite this script. Control of the air will still be critical to military success, but how, when, and where it will be achieved are all subject to change. Two fundamental developments make this necessary. The first is the vulnerability of forward-located fixed bases (and, to some extent, even remote air bases) to attack by precision missiles. The second is the extension of counterair weapons engagement zones to unprecedented, almost unlimited, ranges. China has already invested in thousands of surface attack missiles—cruise, ballistic, and hypersonic—launched from a variety of sources. In the Ukraine conflict, thousands of missiles and Unmanned Aerial Systems (UAS) have already been employed effectively. Air forces that depend on a small number of easily targeted, forward-based airfields will not be viable in 2050, and may not be viable today. Similarly, counterair weapons with ranges out to over 1,000 miles and

supported by space-based sensors will place aircraft, such as tankers, that have traditionally operated with impunity, at risk. Against a pacing challenge, the current Joint Warfighting Concept already assumes that, in heavily contested airspace, air superiority can be achieved only episodically through pulsed operations.

There are other incentives to change traditional air domain assumptions. In 2050, the threat of nuclear responses will also serve as a strong deterrent to deep conventional strikes and prolonged conventional bombing campaigns against peer competitors. Penetrating bombers will still have utility for nuclear deterrence, but large numbers of penetrating bombers escorted by fighters capable of penetrating heavily defended airspace will have limited utility, especially given the potential availability of cost-effective, stand-off and loitering weapons.

Cyberspace and the Electromagnetic Spectrum

Any future air or space domain operations will take place in an environment where the ability to acquire, transport, and use information will be contested in both cyberspace and the electromagnetic spectrum. By 2050, the Air Force and Space Force will be operating in networks of integrated and interdependent sensor nodes, communications links, and battle management systems that are highly automated and seamlessly cross lines between traditional domains of warfare. Action at long range will confer an advantage, but the ability to exploit that advantage depends on reliably functioning sources and flows of information. In 2050, we can expect significant resources and force structure to be dedicated to protecting our own sources of information and attacking those of an adversary.

The National Defense Strategy of 2050

The Air and Space Forces do not exist in a vacuum. They serve a national purpose. Given the expected national security environment of 2050, the anticipated changes in technology in that time frame, and the continuously changing character of warfare, what can one expect the National Defense Strategy of 2050 to be, and what can one expect the role of the Air Force and Space Force to be in support of that strategy? We do not expect fundamental changes in the U.S. National Security Strategy, National Defense Strategy, or National Military Strategy between now and 2050. The U.S. role in the world has been stable for several decades. We must defend our homeland from attack. We will lead coalitions of nation-states that share our values and interests in defense of those values and interests. Our highest priority military strategic goals are deterrence of either nuclear or conventional war and the ability to defeat aggression against the United States or any of its allies. Beyond those core goals we also seek to preserve peace and stability in the world and compliance with norms of behavior associated with civil society and peaceful international cooperation, commerce, and dispute resolution. We seek these goals through the integrated use of all elements of power, not just military power. We also do not anticipate that the United States will become an isolationist power by 2050. We are dependent on our partners in the world for success, and they are dependent on us. One team, one fight.

The Department of the Air Force in 2050

Whatever the rhetoric of the time, in 2050, the United States will remain in strong international alliances to which the United States makes unique contributions. Integrated deterrence is the phrase we are using now, and it captures our intent well. By 2050, some aspects of integrated deterrence will remain, and others will change. Hopefully, the nuclear security umbrella that the United States provides to its partners will continue to be effective at deterring nuclear conflict and discouraging proliferation of nuclear weapons. The powerful and agile conventional power projection force that the United States provides, with some elements deployed forward and others able to quickly provide additional capability globally, adds another layer of integrated deterrence that contributes to the security of the United States and our partners. By 2050, there will be a third layer of integrated deterrence: a robust suite of space-based military capabilities that only the United States can provide to its allies and partners. The triumvirate of a nuclear security umbrella, agile power projection, and space superiority are expected to be the centerpieces of a 2050 National Defense Strategy of integrated deterrence.

The Joint and Combined Force of 2050

The Air Force and Space Force are also critical parts of both the Joint and Combined Force. In addition to defending the homeland, the Joint Force must also provide both strategic and conventional forces that can protect and, as needed, fight alongside our allies around the world to defeat aggression against those allies. The United States must also be prepared to react globally to crises wherever they may occur and on short notice. As a result, the United States will continue to have forces at home prepared to protect the homeland and project power anywhere in the world, and forces deployed forward ready to fight in support of our allies, especially those most under threat of aggression. Our Air Force and Space Force must support all these requirements. The Air Force and Space Force of 2050 must also be designed and structured to conduct and support integrated operations in Joint and Combined overarching organizations in which each element of the force provides mutually supportive functions where the whole is greater than the sum of its parts.

The Space Force of 2050

The purposes or missions of the components of the Space Force of 2050 will not be substantially different from those fielded or in development today, but their form and scale will change dramatically. The greatest changes will be in the competitive deployment of distributed and disaggregated systems and in the increased and more capable inventories of counterspace weapons systems, both on orbit and terrestrially. This will drive a need for increased human resources even with the integration of AI and automation. It will also mandate deepening partnerships with the private sector to capitalize on commercial and dual-use innovation and with allies and partners developing their own space systems and doctrine. Currently, the Space Force comprises about 10,000 Guardians. By 2050, we can expect the Space Force to be multiples of this number, but still small compared to the other Services. One unknown at this point is the degree to which concerns about stability and resilience are likely to drive the acquisition of back-up systems, either stored on earth or concealed in orbit, that can be fielded responsively in a crisis or during a conflict.

Space Domain Awareness and Control

In 2050, the United States will need a full suite of on-orbit and terrestrial assets designed to provide continuous and precise tracking of adversary space systems. Assuming there is no negotiated or enforceable limit on the positioning of military assets, including weapons in space, it will be a prerequisite for defensive or offensive space operations to have as complete and current space domain awareness as possible. The presence of large numbers of international military, commercial, and civil space assets will dictate that space domain awareness systems be highly automated and able to provide current information to decision makers in real time, including indicators of anomalous behaviors, risk assessments, and analysis of alternative courses of action. The potential for signature management, deception, and unwarned launches or maneuvers will make this function challenging, but it is a prerequisite for deterring or defeating an attack on U.S. and allied space assets that could be decisive.

Space Force counterspace systems will include a cost-effective mix of weapons, both terrestrial and on orbit. There will be a high premium for deep magazines that can neutralize a large number of threat satellites in a short period of time. By 2050, directed energy systems, both on orbit and on the surface of the earth, are likely to have achieved adequate power levels to meet this need. However, threat responses such as hardening, proliferated architectures, rapid replenishments, and other resilience measures will compound the problem and limit engagement rates. Kinetic weapons designs will have to take into account space debris challenges and the priority of application towards low density high value target sets. Unambiguous destruction and battle damage assessment capabilities will be needed to support Joint Force operations.

Space Force Support to the Joint Force and Combined Force

Surveillance and Targeting. By 2050, the entire Joint and Combined Force will be heavily dependent on real time, space-based surveillance and targeting provided by the Space Force. In general, weapons with longer stand-off ranges will be preferred. As a result, non-organic target acquisition, identification, and tracking will be needed to support weapon allocation and engagement decisions during high spatial and temporal density situations. Even if hypersonic weapons become a major part of the Joint and Combined Force inventory, they will still need in-flight updates for moving targets. Those updates will be provided from space-based sensors and communicated through space-based communications networks. As noted previously, the DAF is already moving away from airborne sensors such as JSTARS and AWACS in favor of space-based alternatives. This trend will continue. In 2050, intelligence needs will still have to be met, often with common sensor systems that can be flexibly tasked and configured to provide data inputs to both warfighting Command, Control, and Battle Management (C3BM) systems and intelligence Processing, Evaluation, and Disseminations Systems (PEDS). Some commercial space-based sensing firms will be successful in the market and partly supported by the government. Wherever possible, these systems will be integrated into multi-use architectures for use by the Space Force and the Intelligence Community, significantly compounding any adversary's calculations about the vulnerability of the overall fleet.

Missile Warning and Track. Through 2050, missiles will remain the preferred weapon for kinetic attack at ranges from line-of-sight to intercontinental. The first step in effective missile defense and in strategic response to a nuclear attack is accurate and timely warning and attack assessment. Once designed for detection and warning of nuclear strike, the missile warning and attack assessment systems the Space Force will operate in 2050 will be integral parts of long-range kill chains designed to detect, assess, and report data on missile threats of all types and ranges, including hypersonic weapons. The resilient architectures being fielded now will evolve and be updated multiple times between now and 2050. Air defense and ballistic missile detection systems will become mutually supportive and networked. Because of their importance to nuclear stability, these systems will be a high priority for reliability and resilience, but they also must be adequately survivable in a conventional conflict.

Communications. The appetite for secure broadband, long-range communications systems will continue to increase through 2050. The Space Force will continue to evolve low earth orbit proliferated systems its Space Development Agency helped to pioneer. Once the shift to proliferated architectures is more mature, we can expect variations intended to increase resilience to attacks of all types as well as more complete communications offerings. The commercial space communications market will have matured by 2050 and is likely to be dominated by a small number of companies. The Space Force should partner with as many companies as possible to increase resilience and wartime surge capacity. Depending on the evolution of the threat, responsive backup capability may be acquired to ensure highest priority communications needs are met in wartime. In 2050, the Space Force will also continue to provide essential elements of the nuclear command, control, and communications system.

Position, Navigation, and Timing (PNT). The Global Positioning System (GPS) is a global service with enormous value to commercial, civil, and military users. The Space Force will continue to provide reliable PNT signals to support all users through 2050 and beyond. This global utility may be upgraded and expanded to provide additional features tailored to military users and to provide increased resiliency in a conflict for all users.

Weather. The Space Force will continue to provide some specialized weather sensing from space through 2050. Most weather data needs are obtained through non-military sources and that will continue to be the case.

Space Access

For approximately ten years the DAF has been acquiring space access as a service provided by civilian contractors. That practice will continue and assured access to space through multiple suppliers will be an enduring policy. As noted earlier, the cost of space launch has declined dramatically and may continue to do so if the commercial demand for space launch continues to increase and if competition continues to spur innovation and drive prices down. It is too early to determine if there is a future for space cargo, however the expectation is that super-heavy launch vehicle development will continue and be used for

space exploration and to move large payloads into orbit. We are already close to the point where launch costs are not a major limiting factor for space access. While the commercial implications of this fact are still uncertain, it does imply that proliferating national security space assets, for both the United States and its potential great power adversaries, will continue.

The Air Force of 2050

While many elements or components of the Air Force of 2050 will resemble current capabilities or those in development, some significant changes can be expected. Overarching trends will be the move to extensive applications of autonomy, including uncrewed aircraft; reduced dependency on small numbers of fixed forward bases; greater reliance on stand-off weapons; and increasing reliance on space-based sensing and communications. Each of the Air Force's five core functions will see major changes. Air superiority will be achieved through extended range engagements and uncrewed collaborative aircraft supported by off-board sensors. Global strike will be achieved with greater reliance on stand-off weapons. Mobility will have to be resilient enough to be achieved in highly contested environments. ISR will be much more dependent on space-based capabilities, linked to organic sensors. Finally, C3BM will be much more automated, integrated, and resilient at all echelons.

Nuclear Deterrence

Between now and 2050, we do not envision a departure from reliance on a triad of capabilities of which the Air Force will provide the air- and ground-launched legs. Sentinel has just been certified to continue in development. The B-21 is moving into production. By 2050, the Minuteman IIIs will have been replaced and a substantial inventory of B-21s will have been fielded. We will also maintain a robust and secure suite of nuclear C3BM capabilities. Given trends and recent developments in both China and Russia, we do expect that between now and 2050 there will be several reviews of our nuclear posture in which nuclear force adequacy, strategic stability, and, possibly, arms control, will play a part. We are just entering a new and more dangerous period of human history with increased risk and uncertainty. We may well need new concepts for dealing with the problem of multipolar nuclear powers, escalation management, the expansion of the range of novel strategic and tactical nuclear weapons, increased nuclear proliferation, and the potential integration of nuclear and conventional weapons. It is possible that in a tri-polar nuclear world without arms control constraints, other steps may be taken to enhance nuclear deterrence and increase strategic stability. These could include a more survivable, mobile ground-based intercontinental ballistic missile (ICBM), an expansion of the long-range airborne leg in some form, additional dual use aircraft, or other means to achieve a larger, more survivable suite of capabilities. We are not considering those options at this time, but they may well be required by 2050 if current trends continue.

Global Conventional Strike

The structure of the Air Force currently emphasizes relatively large inventories of short-range, multi-role, crewed aircraft and a small fleet of longer-range, higher-payload,

crewed aircraft. By 2050, this balance is likely to shift to greater reliance on stand-off aircraft and weapons even though just adding greater range is no guarantee of resilience in the future. While there is no stand-off platform currently in development after the B-21, one could be initiated in the next decade or so and be fielded by 2050. It is also possible that B-21 production may be increased substantially above current projections. Another nearer-term possibility is to provide stand-off weapon release from transport aircraft, which has already been demonstrated. Longer-range strike aircraft offer the United States the ability to easily shift combat power from one theater to another and deliver stand-off weapons at reasonable scale. Given current trends in potential adversary counterair weapons engagement zone distances, even long-range bombers carrying stand-off weapons may be vulnerable to anti-air missile threats between now and 2050. As a result, a means to provide adequate survivability features, or tactics, techniques, and procedures, and, potentially, novel platform designs, may have to be developed as well.

Tactical Air Forces

It is a given that the Air Force will be fighting forward with our allies and that we must have the capability to defeat aggression by land or by sea, through 2050 and beyond. The Air Force will continue to move toward a family of systems approach to tactical air force composition in 2050. By 2050, the technologies described earlier will have matured and transitioned to fielded capability. In particular, automation and other forms of AI will be in wide use but will not completely replace human operators. The Air Force has already awarded contracts to build uncrewed Collaborative Combat Aircraft (CCAs), or lethal loyal wingmen Unmanned Aerial Vehicles (UAVs) that would be under the control of a crewed fighter. A planning factor of 1,000 has been provided, but it will be some time before final inventory objectives and crewed-to-uncrewed ratios are determined. The next increment of CCAs, which is only a year or two behind Increment 1, will be designed in conjunction with the Next Generation Air Dominance (NGAD) platform and with concepts for more resilient tanking, including the possibility of a Next Generation Aerial Refueling System (NGAS). There is an ongoing effort to define the requirements for all the platforms in this suite of capabilities. Major drivers for these requirements are concerns about the vulnerability of fixed forward airfields, realistic operational concepts to achieve national objectives against the projected threat, and the ranges and delivered effects needed to be mission effective. These efforts are intended to inform the President's Fiscal Year 2026 budget and will have longer term impacts on the Air Force of 2050.

Information Dominance (ISRT/C3BM/Cyber Forces)

The Air Force and Space Force of 2050 must have the ability, with the other Services, to dominate the information domain. The entire Joint and Combined Force will be highly dependent on the Space Force for defeat of an adversary's space-based sensing and space-supported, long-range automated kill web. The balance of the Intelligence, Surveillance, Reconnaissance, and Targeting (ISRT) function will shift from air assets to space assets. However, for resilience and redundancy, some airborne ISR capacity will remain in the Air Force. Space-based sensors and remaining airborne sensors, including organic sensors on tactical aircraft, will support integrated air C3BM systems. Currently significant C3BM

capacity resides on airborne ISR platforms, but that will not be possible in 2050. By then, BM functions will have to operate from a combination of airborne and resilient ground-based locations connected through robust, space-based communications nets. The entirety of this networked suite of capabilities must be cyber secure. Cyber elements of the Air Force will expand to multiples of their current size in the order of battle to execute the missions of defending Air Force networks and attacking adversary networks. The elevation of the cyber units in the Air Force to a command that reports to the Secretary and Chief of Staff of the Air Force under the reoptimizing for great power competition decisions are part of this process.

Mobility Forces

In 2050, the Air Force is expected to have similar Joint Force mobility requirements to the ones it meets today, but in a much more stressing threat environment. The mobility assets of today's Air Force are largely commercial derivative large aircraft (tankers), or large military aircraft (transports) designed to operate in a low threat environment. Well before 2050, this will have changed, putting these platforms into a contested Weapon Engagement Zone (WEZ) in stressing scenarios involving a peer competitor. The demand for these aircraft is also high, especially in the early days of a conflict. These aircraft currently have minimal survivability features and lack connectivity needed for situation awareness and resilience. The Air Force recognized the vulnerability of tankers two years ago and initiated an analysis of alternatives that will feed the decisions on NGAS, NGAD, and CCA Increment 2 currently being analyzed. There will be a need for some mix of refueling capacity in 2050, but the details of the solution to that problem and how it fits into the force overall have not been resolved at this time. The case is similar for transport aircraft. Nevertheless, the Air Force of 2050 will include both tankers and transports to meet the Joint Combatant Commander's needs for a variety of missions. Both classes of aircraft can be expected to have a mix of embedded and externally supported survivability features.

Airmen and Guardians

The realities of manning the Air Force and Space Force in 2050 demand changes to how we recruit and maintain Airmen and Guardians. The DAF recognizes the changing nature of warfare requires a different kind of very technical, high-skill talent pool that makes recruiting the right Airmen, Guardians and civilians that much more challenging.

Specific "Tech Tracks" for both officers and enlisted members in the Air Force, undertaken in 2024, are designed to meet the needs of the service while attracting potential service members from a new pool of young people. Additionally, reinstating the Warrant Officer program was specifically designed to enhance recruiting in the cyber and information technology areas.

In the Space Force a redesign of the Officer Training Course and career paths for officers in the areas of intelligence and cyber is nearing completion.

Conclusion

In 2050, unless there is a fundamental change in the direction of international affairs, the United States will be facing a peer competitor in the Pacific and a near peer competitor in Europe. By that time, existing trends in technology maturation will have moved forward considerably, and new trends will have become evident. China is doing everything it can to exploit the opportunities that emerging technologies are providing to field forces designed to defeat the United States in the Western Pacific, especially in space and in the air. By 2050, if not well before, the Air Force and Space Force will not be competitive unless we make substantial improvements in how these forces are equipped, trained, and operated. We can no longer acquire new systems and assume they will be dominant for decades. This report lays out that situation and describes the changes that will be needed to remain competitive. The National Defense Strategy is sound, but the ability of the Air Force and Space Force to support that strategy is at risk if we do not have the necessary resources and move aggressively in the direction described in this report.