American Aerospace Power
Choosing to Lead in the Twenty-First Century

Harry A. Foster
Maj Dylan A. Bell
Capt Darren R. Turner

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Foreword

Rarely does a work of military strategy elevate its vision beyond merely military concerns. Rarer still are strategies that compel the wise engagement of our military with the broader polity they serve—the American people. The strategy you are about to read is this rare exception. *American Aerospace Power: Choosing to Lead in the Twenty-First Century* offers a compelling vision for sustaining the American way of life for the next hundred years.

As challenges to world order and the American way of life appear around every corner, our instinct might be to ask, "What do we do now?" Wiser strategists, however, ask *where have we been*? Where have we historically gained our strength, preserved our advantage, and developed one of the most prosperous societies in the history of the world? This essay looks forward by first looking back, and it finds that America's strengths as an *aerospace nation* laid the foundation for our unmatched prosperity over the past 100 years.

This is a story of civil-military partnerships at their finest, harnessing the innovation of industry, the insight of academia, the strength of the military, and the sweat equity of the American worker. Together, this aerospace nation propelled Charles Lindbergh across the Atlantic in 1927, rocketed Chuck Yeager through the sound barrier in 1947, landed Neil Armstrong on the moon in 1969, and hung the constellation of satellites that give communication, timing, and navigation to the entire world. As the authors make clear, American aerospace strength has been the fruit of toil matched with vision, not a birthright.

The challenge for a new century is to reclaim our aerospace roots as a nation. As the pace of technological change accelerates, and with it the potential threats to our American way of life, our aerospace power may prove to be the margin of our survival. The strategy outlined in this essay appeals not to a military audience, but to the American people; the task ahead of us is a *national* task, not just a military one. Our approach needs to be comprehensive once again, uniting our societal strengths in industry, technology, manufacturing, and innovation. *American Aerospace Power* gives us a path forward, equally grand in its scope and detailed in its recommendations.

On balance, our national strengths are legion. The United States has been richly endowed with favorable geography, natural resources, oceans east and west, allies north and south, and a deep multiculturalism that attracts global

talent to our shores. We face critical challenges as a nation, but we face them from a position of strength. Our capacity to flourish as an *aerospace nation* may prove to be our greatest strength of all.

STEVEN L. KWAST
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About the Authors

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Maj Dylan A. Bell and Capt Darren R. Turner are instructors at the Squadron Officer School.

Introduction

In 2016 an estimated 3.6 billion people will board a commercial airplane. That is more than one-half of the number of people on Earth. As they connect their devices to Wi-Fi and adjust their on-demand in-seat entertainment systems to better sit back, relax, and enjoy the flight, few will concern themselves with the technology that makes their journey and communication possible or with the high degree of safety and dependability that makes air travel so routine. Fewer still will consider the broader impact of aerospace power on the world: how it has shaped the globalized economy and provided military advantage. If any took the time to really consider the topic, they would discover that aerospace's innovation and leadership is distinctly an American story.

Figure 1. Air travel is now the safest, most efficient mode of transportation in the United States

This is a short story of American aerospace power—its technology, its people, and its importance to future American prosperity and security. This story is important because the advantage the United States enjoys today as the world's economic and technological leader is due in large part to its achievement and investment in aerospace. But, it is also a cautionary tale. America's leadership position in aerospace is under threat commercially and militarily, not necessarily because of the actions of others (though they are omnipresent), but because American leadership is taken for granted. It is worth remembering that America's leadership position in aerospace was a choice, not a birthright. Without Congressional action and the continued support and interest of the American people, it is a leadership position other nations are posturing to assume.

An Aerospace Nation by Choice

While geography marks the United States as a maritime nation, it is a uniquely *aerospace nation* by choice. This is not simply because the airplane was invented here over a century ago; rather, it is because the United States embraced aerospace as no other nation did for the better part of the twentieth century. The speed of technological advance in aerospace allowed Charles Lindbergh, the first man to fly the Atlantic nonstop in 1927, to know Chuck Yeager, the first man to break the sound barrier in 1947, to shake the hand of Neil Armstrong, the first man to walk on the moon in 1969, and to fly the Atlantic in a 747 Jumbo Jet—all before his death in 1974.

Armstrong would live to see a second technological wave in cyberspace founded on the vast computer- and communications-based research for aerospace projects from the 1960s to the 1980s. Microsoft's Bill Gates, Cisco Systems's Leonard Bosack, Apple's Steve Jobs, and even Facebook's Mark Zuckerberg would build mega-empires based on this aerospace-related seed corn and, in the process, connect the world.

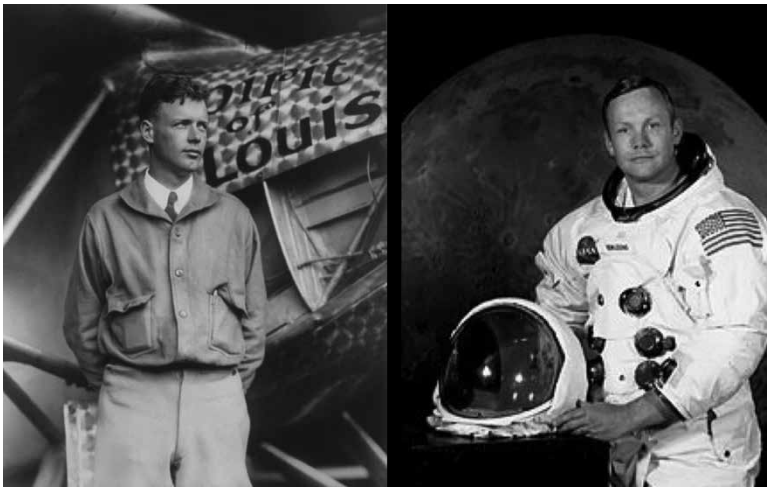

Figure 2. (Left) Charles Lindbergh, first to fly the Atlantic, 1927; (Right) Neil Armstrong, first man to walk on the moon, 1969

The rapid development of aerospace expertise in the United States did not happen through the ordinary force of the private sector. It resulted from investment choices in government-funded research and development (R&D) as well as risk acceptance by the president and Congress.

The demands of a world war and a cold war made much of this research necessary. The impact of technical advances reached far beyond the government realm, however. American airplane companies led in the jet age with innovations like the Boeing 707 and Douglass DC-8, because Congress chose to invest in jet refueling-tanker research in the early 1950s to allow

bombers based in the United States to hold targets at risk at intercontinental distances. The United States entered the race to the moon and gained massive spin-offs in technology because of a president's vision and public support.

These efforts produced countless technology seedlings that we take for granted today. Consider the modern smartphone used by half of all Americans. It places arguably the most powerful information tool ever conceived in the palm of our children's hands. It connects to a store of knowledge that contains 4.5 billion pages of information; places this information into the context of time and location (within six feet); displays the phone's orientation and acceleration, accesses what others did, saw, or heard before nearby; shares what others are seeing, hearing, and doing right now; and stores the user's preferences. It then correlates this information on ultraresolution, spatially accurate maps that would have been highly classified just 20 years ago.

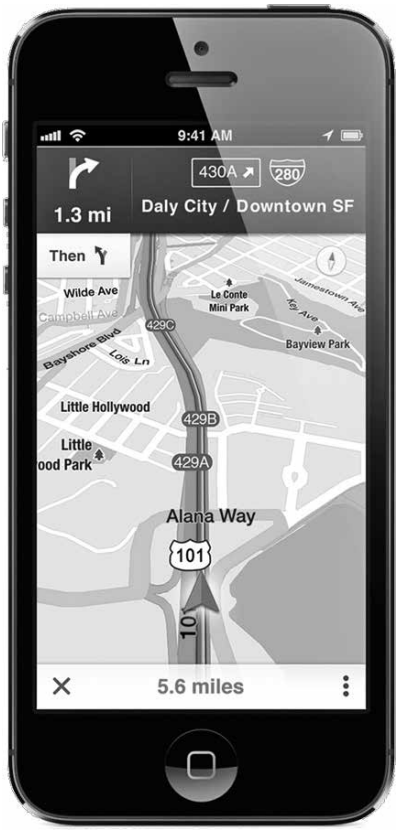

Figure 3. Smartphone, circa 2015

The file exchange protocols, optics and cameras, accelerometers, power sources, touch displays, and transmitter technologies incorporated into these devices have their roots in aerospace R&D. The key enabler behind

these phones and their networks are highly accurate timing signals from the Air Force's global positioning satellites that allow the networks to synchronize and the phone to determine its position. These are the same signals widely used by the military to locate and guide weapons to targets in defense of the interests of the United States and its allies.

The Global Positioning System (GPS), now indispensable as a common timing standard for global data networks and prolific as a positioning tool for just about everything, is an example of aerospace choices previous Congresses have made and presidents have supported. Unconvinced of its relative military utility, the services canceled the system for a brief period between 1980 and 1982. Congress and the Air Force, with advice from the Department of Defense (DOD), made difficult trade-offs to fund the system, never fully understanding its civilian uses or potential. Both made a bet on the promise of what a clock in space might produce. Today, the results are, of course, epic.

The fruits of the choice to invest in leading edge aerospace technology development over decades changed the world. Supremacy in aerospace provided US corporations with a competitive advantage in the marketplace, spurred globalization, and enabled the United States to maintain its position as the world's global economic leader at the turn of the twentieth-first century. Along the way, these choices also enabled the United States to prevail in the Cold War as part of an aerospace-based competitive strategy against the Soviets and to shape the post–Cold War order.

Aerospace Power: Providing Options to Offset the Advantage of Others

From the dawn of the nuclear age, aerospace power fueled two separate political-military strategies designed to overcome Soviet military advantages in the darkest days of the Cold War. Both of these "offset strategies" were essential to avoid the Soviet leadership's cost-imposing plays designed to lure the United States into an unsustainable set of military investments. In the early 1950s nuclear-armed, long-range Strategic Air Command (SAC) bombers provided a way to offset Soviet conventional power in Europe. Rapid developments in transonic flight and air-to-air refueling enabled this approach. Investments in continental air defense and the Semi-Autonomous Ground Environment, which pioneered electronic collaboration through connection of mainframe computers to radars by phone lines and microwave data links to form the first large-area data network—a key technology for going to the moon and, later, building the Internet—further reinforced these developments.

Figure 4. B-47 bombers in the early 1950s

A decade later, massive investments in hypersonic research and ballistic missile technology changed the competition again. The United States would field four intercontinental ballistic missile (ICBM) systems and one submarine-launched ballistic missile system within seven years. Meanwhile, hypersonic research forced the Soviets to channel large investments into new air defense designs to counter high-altitude, high-speed bombers like the Mach 3 North American XB-70 Valkyrie. Although the United States did not field this bomber, development and flight test of prototypes drove massive Soviet investment into countermeasures. This allowed the United States to compete at a lower cost rather than matching the Soviets solider for solider and tank for tank.

Figure 5. Minuteman ICBM launch

Later, as Soviet ballistic missiles grew in number and Soviet air defenses grew in strength in the 1970s and 1980s, the United States turned to a combination of enhanced space capabilities and radar-defeating stealth to offset the Soviet's military advantage. Space surveillance programs, funded through the National Security Agency and National Reconnaissance Office, provided leaders with real-time indications of missile warning and informed estimates of Soviet strength and locations. Meanwhile, stealth programs like the F-117 provided survivable deep strike in central Europe, while the B-2 threatened strike from intercontinental range into the heart of the Soviet Union. The Strategic Defense Initiative, or "Star Wars," funded research into space-based missile defense that threatened to offset Soviet investment in ballistic missiles by destroying the missiles inflight before they could reach their targets. Like the XB-70, Star Wars technologies caused a massive Soviet reaction despite the fact the system was never fielded.

Figure 6. B-2 stealth bomber

Overwhelmed by political, operational, and technical innovation, the Soviets could no longer afford to compete. The Cold War ended peacefully with significant help from aerospace power. It was not an inevitable outcome; it was a strategic choice by US leaders to invest in aerospace to build the US advantage.

Cold War Aftermath: Success, Divestment, and Transition

The United States concluded the Cold War triumphantly in 1991 but was challenged near the very end of that era when Iraq invaded Kuwait in the fall of 1990. A coalition led by the United States ejected Iraqi forces from Kuwait with a speed and effectiveness unprecedented in modern warfare.

The US aerospace reconnaissance-strike complex was front and center—finding critical nodes deep inside Iraq, striking them with high precision, and crippling the Iraqi air force and army across its breadth and depth. The decisive performance of aerospace power against Soviet-manufactured front-line air defense equipment and the impact of US intelligence, stealth, and precision weapon capabilities were impressive. The performance transformed US views on military risk as the president and Congress approached the New World Order and its decisions on aerospace investment.

Figure 7. US airpower over Kuwait, 1991

With absolutely minimum losses against what should have been a competent military force, US aerospace power provided presidents with a new, lower-risk tool for intervention. No-fly zones and punitive strikes would allow the United States to keep Saddam Hussein in check for more than a decade. In the 1990s aerospace power also enabled the United States to intervene twice to end ethic cleansing in the Balkans. In Kosovo, it was largely responsible for winning a war without a combat loss of life.

The overwhelming advantage aerospace power provided began to change views on aerospace investment as the United States entered a unipolar world. Aerospace advantage, coupled with the end of the Cold War, enabled the United States to reap a peace dividend that, paradoxically, permanently reduced the size of the US aerospace industrial base. As budgets shrank, investment in US aerospace slowed and the aerospace industrial base consolidated dramatically in the 1990s. Rockwell International's aerospace components and McDonnell Douglas merged with Boeing, Martin Marietta Corporation merged with Lockheed, and Grumman Aerospace Corporation merged with Northrop Corporation. Lockheed's exit from the commercial market and the merger of McDonnell Douglas and Boeing left one major commercial aircraft manufacturer in the United States—even as European aircraft manufacturer, Airbus, began its rise.

Meanwhile, the fast-growing information technology sector began to replace aerospace as the prime career destination for young engineers. Indeed, by 2014 Google's market value alone, nearly $400 billion, was more than double that of General Dynamics Corporation, Northrop Grumman Corporation, Lockheed Martin, and the Raytheon Company put together.

At the same time, as fewer American students filled science, technology, engineering, and math classes in US universities, foreign students stepped in to fill the void, beginning a proliferation of technical knowledge outside the United States.

Stealth gave the United States an absolute advantage against Soviet-designed equipment, which composed the air defenses and air forces of the most-likely US adversaries. This allowed reduced US investment in electronic warfare, which had been pivotal to a strike force's survivability prior to stealth.

The combination of the growth in computational power, the establishment of US space superiority, and the proliferation of fiber communications lines with large bandwidth capacity enabled a golden age of intelligence gathering using aerospace. While collection platforms such as the strategically focused SR-71 were eliminated, ubiquitous satellite communication, improved sensors, GPS guidance, massive storage, rapid computer processing, and largely uncontested threat environments enabled the United States to reinvigorate its reconnaissance remotely piloted vehicle programs that had been largely abandoned in the 1970s.

The proliferation of precision weapons in US aerospace forces changed the economics of warfare. One precision weapon could inflict the same damage as dozens of unguided munitions. In Operation Desert Storm, laser precision guidance required pilots to release their weapons one at a time. By 1998 incorporation of low-cost GPS guidance kits onto "dumb" weapons removed this restriction. This significantly multiplied the striking power of each aircraft and dramatically compressed the time required to move through a target list. The impact of ubiquitous precision guidance was such a shift in capability that one commentator argued a single B-2 could deliver the same destructive effects as 1,000 B-17s in World War II.[1]

Figure 8. Low-cost tail kits on "dumb" bombs provide precision guidance from the GPS

This "one bomb, one target" precision capability convinced the DOD and Congress that the number of fighter and bomber aircraft could safely

be reduced. As a result, purchases of Air Force F-16s and F-15s ended, though the Navy continued its F-18 E/F program. Acquisition of the long-range B-2 stealth bomber ended at 20 aircraft, and production of the F-22 fighter ended at 187.

Precision, along with the general supremacy of US aerospace, also enabled the United States to reduce its reliance on nuclear weapons. Several bilateral agreements between Russia and the United States saw reductions of strategic and tactical weapons as well as an end to underground testing. SAC stood down, the nuclear mission for the B-1 ended, the bulk of the B-52 force was retired, the new Peacekeeper ICBM was removed from service, and several *Ohio*-class ballistic missile submarines were converted to conventional strike platforms. Development on new nuclear weapon designs ended as well. The focus of the nuclear industrial base turned to monitoring the safety and reliability of the stockpile using analytic methods.

Desert Storm and its aftermath also set a series of slow-moving, geostrategic, and military reactions into motion. Following Desert Storm, the United States began a significant, permanent US military presence in the Middle East. This presence inspired radical Sunni groups to lash out with a series of high prolific attacks, culminating in the 2001 attack on the World Trade Center.

Desert Storm and China's inability to contend with the US military dissuasion in the 1996 Taiwan crisis launched the Chinese government on an aggressive program of military reform, even as that country opened its economy to the globalized system that led to an economic miracle. Overcoming US advantage in aerospace became an obsession for the Chinese military in the subsequent two decades. Denying the effects of precision and power projection became the focus of Chinese strategy. As a result, China continued a longstanding tunneling program to move military capabilities underground; modernized its air force; developed a mobile, fiber-based air defense system; and fielded short- and intermediate-range precision-guided cruise and ballistic missiles designed to target US airbases and carriers.

Meanwhile Russia, struggling to reinvent itself after the collapse of the Soviet Union and finding itself unable to compete with Western military power, quietly began to increase its reliance on nuclear weapons for its defense. As US precision capabilities multiplied, Russia warned the West that an attack with precision weapons would be considered tantamount to a nuclear attack. In addition, Russia retained a significant space capability and developed new capabilities within cyberspace as technology advanced in the 1990s.

Iran, India, and North Korea successfully developed nuclear weapons, and Syria and Libya would try to do so as well, in an effort to dissuade an attack from neighbors or the United States. Iran also developed swarm

techniques, using small boats designed to overcome US aerospace advantage and to threaten oil shipments in the Persian Gulf.

Cyberspace, Accelerating Technological Change, and 9/11

Three technological factors converged in the 1990s that launched globalization and further changed the nature of aerospace power. First, the rise of the World Wide Web, the rapid spread of fiber communications around the globe, and the growth of cyberspace began a process that deeply connected societies and enabled sharing of human knowledge on an unimaginable scale.

Second, the continuation of Moore's law saw processing power and memory double every 18 months. This meant that the same processing power of the multimillion dollar ASCI Red supercomputer needed to maintain the US nuclear stockpile in 1995 could be found in the Microsoft Xbox One in 2013 at a cost of less than $400 around the world. For less than $2,500, seven Xbox Ones connected in parallel provided the supercomputer processing power originally needed to sequence the human genome in 2000.

Figure 9. ASCI Red, fastest supercomputer, 1995

Third, the rapid adoption of connected devices by people, governments, and corporations around the world proved disruptive, connecting 2.4 billion people (about one-third of the world's population) to the Internet by 2014. It enabled terrorist groups to collaborate regardless of geography, provided an effective communications tool for insurgents to get their message out quickly, opened pathways for industrial and military espionage, and enabled access for attack or disruption. It also led to the rise of big data to map and understand millions of relationships for businesses to find customers and governments to find bad actors.

The terrorist attacks of 9/11 were enabled, in large part, by the growth of cyberspace. E-mails, text messages, and wire transfers from overseas were a key part of al-Qaeda's operations. Cyberspace was certainly front and center in the US response. It contributed not only to finding space to locate terrorist networks and their associates but also served as a communications vehicle to connect the intelligence assets of nations around the world to share massive amounts of data.

Cyberspace, combined with aerospace power, was instrumental in defeating the Taliban deep inside Afghanistan. Information, connectivity, precision, and direct delivery of supplies coupled with an enemy choosing to fight by conventional means in an uncontested aerospace environment, turned the "graveyard of empires" into a killing field.

Just as in Desert Storm, aerospace power provided an overwhelming advantage to a ground force—this time to the coalition's Northern Alliance proxy force. A combination of commercial fiber between the Unites States and Europe and space connections between Europe and Central Asia enabled remotely piloted vehicles based in Pakistan and operating over Afghanistan to be flown from Nevada and their sensor data to be shared by secure means to intelligence specialists collaborating on networks spread from Germany to Virginia to California to Hawaii.

Figure 10. Joint terminal air controller on horseback in Afghanistan, 2001: the business end of a massive aerospace effort spanning the globe

It enabled air-refueling tankers, fighters, and bombers based literally thousands of miles apart to be synchronized with remote, ground-based joint terminal air controllers. Pilots took off without any idea of the target or timing. Planning was executed virtually and in real time.

The C-17 airlifter showcased its extreme short-field landing capability to deliver food, weapons, and ammunition directly to small, unimproved airfields from thousands of miles away. This direct delivery capability using large aircraft was unprecedented in warfare. It allowed the United States to

move about half the cargo and troops used in Desert Storm into Afghanistan and surrounding countries with 80 percent fewer sorties in the first year of the war.

Figure 11. C-17 delivers an armored vehicle to austere airfield

In 2003 aerospace power responded to another crisis in Iraq. After another rapid and successful US invasion, however, the Iraqi insurgency began. An insurgency movement in Afghanistan soon followed. The limits of aerospace power quickly emerged as a thinking enemy sought alternative means to counter it.

Insurgents, clustered tightly with the civilian population, represented an asymmetric approach to US aerospace reconnaissance-strike complex. The targets, usually individuals or small cells, were hard to find. They usually operated in urban or mountainous areas, which limited the opportunity to strike when these individuals were found. As the insurgency grew in both countries, improvised explosive devices imposed cost on US forces and proved difficult to locate using existing airborne sensors.

Finding targets became increasingly important to success for aerospace power as striking targets was. Commanders had to choose between focusing aerospace capabilities on finding explosive devices and finding insurgents. Aerospace companies and intelligence agencies rushed to develop and produce remotely piloted vehicles, networking the sensors and weapons to meet the demands of this hider-finder competition.

Figure 12. MQ-9 Reaper remotely piloted vehicle

The networked approach to warfare, fielded for Iraq and Afghanistan, was developed in a relatively permissive cyber environment. US cyber capabilities were hastily assembled given the pace of developments. Concepts that seemed logical and appropriate in the early 2000s did not anticipate the difficulty of overcoming cyber vulnerabilities or cyber espionage by the late 2010s.

The demands of war slashed funding for aerospace and shifted it to ground forces. Within the remaining topline budget, the war drove new aerospace budget priorities, derailed long-term investment plans, and refocused aerospace research development. Long-term research funding was slashed to meet the immediate needs of the war. For example, from 2000–2012 company-funded R&D at the top US defense firms dropped from 3.5 percent to 2 percent of sales. By contrast, the leading commercial companies invest roughly 8 percent of company sales in R&D.

The high demand for aerospace assets over 25 years of no-fly zones and America's two longest wars also rapidly aged the force. The need for continuous overwatch of US forces added thousands of hours to KC-135 tankers and B-52s bought during the Kennedy administration. Today, the grandsons and granddaughters of the original maintenance personnel struggle to keep these fleets going. The stress was especially acute for the newer B-1, F-15, and F-16 fleets funded principally during the Reagan administration. These fleets, the work horses of the Air Force, are exhausted and showing their wear. Meanwhile, the C-17 fleet, among the

newest in the Air Force, was flown with heavy loads at twice the normal rate of the rest of the transport fleet throughout the period. This will move forward by decades plans for replacement.

Toward 2035: Shifting Global Competition, Increasing Threats, Time for New Choices

The aerospace investments made in the 1980s and early 1990s proved their worth, providing the United States with a decisive advantage to defend US interests for over two decades. But the return on these investments is now diminishing as this force shows its age, mechanically and technologically. Worse, others are bringing new technologies and asymmetric tactics onto the scene to challenge US aerospace advantage as never before. Since the end of the Cold War, competitors have been watching, learning, and calculating. Storm clouds are building on the horizon.

Today's aerospace force faces four overlapping negative trends that threaten to reduce its impact going forward unless new choices and investments are made by the president and Congress. The American people must support these new choices. As in the 1980s, the choices made today will set US capabilities for decades to come.

The first negative trend is that existing US aerospace assets need massive recapitalization at a time when budgets are flat and are expected to remain so. The peace dividend taken in aerospace forces during the mid-1990s means a host of capabilities require recapitalization all at once. But the problem is more difficult than that. As the geostrategic environment shifts, many of today's capabilities need to be reimagined through innovation to keep ahead. It is impossible to square the corners of operating a force at high readiness for today's threats, while recapitalizing legacy capabilities; introducing new, leap-ahead capabilities; and living within a flat budget.

Second, the rapid spread of technology—much of it due to cyber espionage—is threatening the traditional US technical lead in many areas. US aerospace and defense no longer pace global R&D as in the 1980s. Indeed, estimates show about 80 percent of global R&D now occurs outside the United States. R&D in the US defense sector is down significantly over the past 15 years. Across the US government, the automatic budget cuts known as sequestration cut $95 billion from R&D from 2013 to 2021. Moreover, a smaller, older aerospace labor force working in a few, large defense conglomerates means innovation may be difficult to achieve without an infusion of new talent and projects to capture this generation's interest.

In addition, government research no longer reduces risk for commercial aerospace ventures to the degree it once did. For example, Boeing's commercial aircraft division has built tube and wing jetliners since the 1950s, despite the fact that more fuel-efficient designs exist. The reason? The US

military has not focused on massive improvement in fuel efficiency in its own designs to transfer to industry (though this may be changing).

Third, technological proliferation is undercutting the distinct advantages that the second offset strategy built in space, precision, and stealth. Disruptive capabilities in cyber and the electromagnetic spectrum threaten to deny the power of networking added in the 1990s.

- The GPS, which depends on radio transmissions from satellites, is becoming increasing vulnerable to jamming, degrading the multiplying effects of US precision. At the same time, others are developing and proliferating alternative precision technologies. This proliferation of precision makes fixed assets like power stations and airfields extremely vulnerable, threatening the ability of the United States and its allies to project power in the same way it has for the past 60 years.
- Modern surface-to-air missile systems and the introduction of powerful lasers are reducing the survivability of aircraft and weapons. In tandem, the vulnerability of space assets to attack, jamming, or other inference also threatens to undercut the cornerstone of the second offset strategy. In 2014 nine countries had space-launch capability and 1,167 satellites operated by 35 countries were in orbit. The opportunity for strategic surprise in space is growing. Together, these developments threaten to reverse the economic advantage of the US reconnaissance-strike complex that enabled the United States to locate targets globally from space and then employ a small number of aircraft to strike a large number of targets.
- The processing power offered by supercomputers on a chip is reducing the outsized stealth advantage the United States has enjoyed for 25 years. Adding these powerful processors to old radars threatens to improve their capabilities substantially and is affordable.
- Cyber attacks threaten to unravel the speed and efficiency of the US reconnaissance-strike complex and deny the current method of operating remotely piloted vehicles.

Fourth, the United States faces a broader set of regional challenges leaving Afghanistan than it had going in to the conflict. Although the United States does not seek conflict with either China or Russia, both countries seem intent on carving out a sphere of influence in their near abroad, directly threatening US allies and interests. Meanwhile, a budding Sunni-Shia civil war emerged in Syria that rapidly transitioned into a battle for Sunni Islam. All of this is happening even as Iran continues its pursuit of nuclear weapons, inviting proliferation by others. Across these regional challenges, new strategies are emerging combining elements of irregular warfare, conventional warfare, and counterintervention measures designed to undercut US aerospace power and dissuade US action. Moreover, each regional

challenge is unique, varying by geography, alliance structures, stakes, and the aerospace capabilities required to contend successfully.

The Chinese threaten their neighbors' sovereignty, using a combination of civilian fishing fleets, its coast guard, and surface navy to squat on disputed claims in an attempt to improve the legitimacy of its claims under international law. Meanwhile, its military is using precision ballistic missiles to threaten US air bases and carriers in the region to deny US aerospace power projection. This maritime irregular warfare activity, combined with counterintervention capabilities, is part of an integrated strategy to undercut US influence and security guarantees to allies and partners.

Russian advances into Georgia, the Ukraine, and Crimea under the pretense of protecting ethnic Russians reflect a similar intent to increase its sphere of influence. Instead of fishing fleets, the Russians have preceded these movements with insurgent and cyber activity designed to undercut local governance. Russian emphasis on nuclear use is intended to dissuade NATO from overt involvement. Russian violation of the Intermediate-Range Nuclear Forces Treaty is also designed to intimidate the populations of Central Europe from becoming involved.

Finally, the combination of a Sunni civil war overlaid on a Sunni-Shia civil war in Syria and Iraq and beyond presents a nearly impossible military problem. The specter of a nuclear exchange increases the risk, potentially drawing in the United States on a large scale.

Needed: A Third Offset Strategy

These trends do not paint a happy picture for US power-projection capabilities. As we think about adapting to a world where the global environment's rate of change is accelerating, our traditional view of winning and losing are giving way to very blurred categories. The concepts of enemy, warfare, battlefield, weapon, victory, and allies are very different today than they were just 10–20 years ago.

The first two offsets had a pretty clear motivation with a specific Soviet capability. The United States knew what it needed to offset, and US aerospace technology helped to do that.

As the United States considers a third offset, two major background threads must be addressed. First, the United States must surmount the ruts of its own status quo (for example, budgets, aircraft age, and acquisition processes) and advance paradigmatically rather than incrementally. With the Soviet Union gone, the United States has become, in some ways, its own worst enemy through bureaucratic inertia.

Second, a third offset must address the rate of change in the global conflict environment. The United States does not know where the next threat is coming from, what form the conflict will take, what medium it will be in, who comprises the threat, or whether our adversaries are state-based or

hyper-empowered individuals. The next offset needs to counter the massive ambiguity in our threat perception more than ever before.

The goal of a third offset, then, should provide the United States with a capability to undercut the counterintervention strategies being pursued around the world. This step would provide the United States with the freedom of action, even in highly contested environments, to address uncertainty. To do this, the United States retains advantages that others do not have—strong alliances, a creative workforce, and a knack for innovation. These advantages should figure prominently in the president's and Congress's choices on a possible third offset. The key question is "how?"

The Cold War choices were characterized as offsets of quality over quantity. A third offset will likely be characterized as choices of innovation over imitation. The seeds of success in this future competition lie in bounding and understanding complexity coupled with the speed and flexibility of a reengineered US reconnaissance-strike complex to act and adjust with a speed no other conflict medium can match. To do this, the United States must retain its global reconnaissance advantage, mitigate threats against precision, and find ways to operate even when forward basing is under threat. This will require systems engineering techniques applied across the aerospace reconnaissance-strike complex, experimentation with new warfighting and logistics techniques, and a new spirit of innovation in America's aerospace industrial base.

A third offset begins by tackling tough problems within the US defense bureaucracy and Congress. Emphasis on platforms, today's ultimate expression of military capability, must be replaced by a networked view of capabilities. Data fighting will likely be more important than dogfighting in this future environment. Future capabilities rest among a group of connected capabilities. Platforms remain important, but the United States will deter or not deter based on how well it can operate its reconnaissance-strike system as a whole.

Budgetary and program risk must be expressed not only in individual program terms (for example, a ship, an aircraft, a missile) but in systemic terms as well (for example, the reconnaissance system, the decision system, the strike system). This larger, systems-level view of defense programs is a significant paradigm change for the US military and Congress. If the United States does not move in this direction, however, a third offset strategy may not be fully executable.

Next, the United States must assess the available technological opportunities and make some investment choices. The following short list suggests where these opportunities lie. As with previous offsets, these investments should produce significant opportunities for commercial spin-off.

Additive manufacturing. Materials and manufacturing are representative of the most basic level of opportunity. The advent of additive manufacturing and 3D printing potentially can change the cost curve of future

weapons systems and could transform current concepts for logistics support. The Cold War choice between quality and quantity may no longer exist. Additive manufacturing may make possible high quality at high quantity at an affordable price. The Materials Genome Project, which assembles new materials at the atomic level, may offer materials with novel qualities that change the cost curve for production.

The private sector is currently driving much of this innovation, but military investments in this area could result in new, lighter structural materials for use in aircraft and vehicles. In addition, the ability to print on demand could restructure the defense industry, acquisition system, and logistics support systems as a whole. For example, whole classes of weapons could be designed and tested but not built in quantity unless needed. Spare parts may not need to be produced in large quantities, warehoused for decades, moved to the war zone, and then returned for repair.

Quantum computing. Quantum computing offers the ability to handle massive flows of data and sort it much faster than conventional computers. Connected sensors and databases of the future are the ultimate big data problem, far surpassing the Wal-Mart and Goggle examples of today. A breakthrough in quantum computing would provide the United States a leap ahead in capability. Commercial spin-offs could include optimizing air traffic flows into busy airports, relieving traffic congestion by adjusting stoplights in real time, or, when combined with additive manufacturing, providing a new wave of predictive, just-in-time delivery.

Fast lasers and clocks. Fast lasers operating at femtosecond speeds are a million times faster than today's GPS powered clocks. These clocks promise to eliminate US military reliance on the GPS for position and time, enable massive data flows, and connect the optical and microwave portions of the electromagnetic spectrum. Like the GPS of the 1980s, we probably do not fully understand the full impact of this technology. The potential for commercial spin-offs is off the chart (think 1,000G on your cell phone). As this area is so high payoff, the United States must lead; it cannot follow.

Unmanned automation. Driverless cars represent the most commonly discussed commercial application of this technological class. It is technology that allows machines to take over lower-level, decision-based functions, leaving humans to make value judgments or sort ambiguous data. Automation would allow military employment from longer distances, eliminating the need for continuous communication with unmanned systems as is the case with remotely piloted vehicles today. From a commercial perspective, automation could improve aviation safety and increase capacity at airports. When put into cars, it promises to reduce traffic accidents, ease traffic congestion, and allow fractional ownership of vehicles.

Fractionation of systems. Closely related to automation is fractionation of systems. One may think of this as a number of smaller automated systems working together as a team to create a capability greater than any single

member. Militarily, this could reduce vulnerabilities against advanced threats in air and space. Fractionation also enables building panoramas from multiple angles to provide better imagery data. An early version was developed to help detect improvised explosive devices in Iraq and Afghanistan. You see the commercial spin-off of this technology every time you watch a 360–degree replay during football or baseball games.

Directed energy. Directed energy consists of coherent light (lasers) or focused microwave energy; each creates different effects. Lasers can offset the proliferation of precision by targeting projectiles in flight, though there are limitations due to weather, speed, and distance. High-powered microwaves can disable unprotected electronic devices. This research will spin off improved battery technology, advanced optics for the smartphone, and windows for high temperate applications.

Aircraft range improvements. The proliferation of precision threatens forward airfields and US air-refueling tanker bases. As a result, fuel efficiency and aircraft range will become increasingly important. New designs for large and small aircraft could include flying-wing concepts and new engine technology to reduce fuel consumption by 40–50 percent. A military production line would reduce development risk, much as the KC-135 tanker reduced development risks for the Boeing 707, and enable a breakthrough in airliner design.

How would these technologies come together to retain US global reconnaissance advantage, mitigate threats against precision, and operate when forward access is under threat? First, these technologies offer the means to fractionate reconnaissance systems in air and space. Creating complexity for others will be as important as understanding complexity for the United States as part of a third offset. Fractionated capabilities require significantly more effort to defeat than a few exquisite platforms, making these capabilities more survivable and costly to defeat. Other steps, such as hosting military payloads on allied commercial systems, could serve to multilateralize a crisis and complicate the political calculus of those considering a broad-based attack.

Second, these technologies offer GPS alternatives for timing and positioning to keep US sensors, networks, and weapons synchronized. This is a vital capability that cuts across all three objectives of a third offset. They could also mitigate threats against precision capabilities by improving survivability of weapons and delivery platforms through the novel integration of stealth, hypersonics, intelligent swarms of expendable weapons, and electronic attack to reduce the effectiveness of modern air defense systems. As with fractionation, this integrated systems approach is costly and requires significant effort to overcome.

Finally, these technologies, combined with new approaches to logistics and the cooperation of allies, could enable the dispersal of a future force on a scale unimaginable today. This, along with new defensive capabilities and

an increased emphasis on resiliency, could substantially reduce threats to forward basing. As with other measures, these actions increase others' complexity, forcing shifts in investment to contend.

Along with increased dispersal, airfield defense, and resiliency measures, an increased emphasis on fuel efficiency and range could reduce tanker requirements. This would remove pressure on forward basing and logistics as well as enable basing diversity at greater distances.

In addition, aerospace capabilities would marry up with undersea capabilities like submarines and unmanned underwater vehicles, forming a "marriage of stealths" to create confusion and provide a persistent presence. Like a marriage, the arrangement would provide mutual support. Each element could "see" and "shoot" in support of the other. The limited payload and sensor look of the undersea force could be mitigated by aerospace forces. Meanwhile, the persistence of the undersea force could ensure targets are held at constant risk, despite the occasional coverage gap of aerospace forces.

Together, these steps would undercut the anti-intervention investments being made by Russia, China, and Iran. The investment to overcome US aerospace forces as described, whether based on land, at sea, or undersea, would be substantial. This cost barrier could reinforce the deterrent effect of US and allied forces. As in the Cold War, it may also spark countermoves by others that require follow-on adjustments to strategy over the coming decades.

Investment in a new, bold strategy would bolster US assurance guarantees to our closest friends and allies. For some, it could forestall choosing to invest in a nuclear capability as a hedge against diminished US conventional credibility. For the world, it would signal US commitments to freedom, democracy, and the rule of law—a world where smaller nations do not live in fear of larger neighbors.

Returning to Aerospace to Defend America's Horizons

How the United States will function in the future security environment comes down to choices. To continue on the same course, whether intentionally or unintentionally, is a choice not to compete via aerospace. The second offset and incremental improvements in capabilities developed since the 1980s have run their course. However, the ambiguity of the future security environment makes the promise of aerospace more relevant than ever before. We must invest and develop new ways to contend.

Unfortunately, there is no silver bullet as there was with nuclear weapons, space, or stealth—no single word descriptor that captures the essence of the offset. Instead, a systems-engineered approach is required to develop an increasingly sophisticated reconnaissance-strike complex. This approach will maintain the US global reconnaissance advantage, mitigate threats against precision, and find ways to operate even when forward access is under threat.

If the United States chooses to pursue this approach, it must increase efforts in long-range R&D; support budget shifts that allow a simultaneous recapitalization and shift toward innovation in aerospace; build incentives for our best young people to study science, technology, engineering, and math; and rediscover the advantage aerospace can provide.

Without such a decision, the United States is headed toward parity in an even aerospace competition. We became an aerospace nation by choice, not by birthright. If we are to remain one, the people and Congress must act.

Notes

1. David A. Deptula, *Effects-based Operations: Change in the Nature of Warfare* (Washington, DC: Air Force Association, 2001), 8.

Abbreviations

DOD	Department of Defense
GPS	Global Positioning System
ICBM	intercontinental ballistic missile
R&D	research and development
SAC	Strategic Air Command

Center for Strategy and Technology

The Center for Strategy and Technology (CSAT) was established at the Air War College in 1996. Its purpose is to engage in long-term strategic thinking about technology and its implications for US national security.

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