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AN AIR FORCE FOR AN ERA OF GREAT POWER COMPETITION

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ABOUT THE CENTER FOR STRATEGIC AND BUDGETARY ASSESSMENTS (CSBA)

The Center for Strategic and Budgetary Assessments is an independent, nonpartisan policy research institute established to promote innovative thinking and debate about national security strategy and investment options. CSBA's analysis focuses on key questions related to existing and emerging threats to U.S. national security, and its goal is to enable policymakers to make informed decisions on matters of strategy, security policy, and resource allocation.

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Cover: U.S. Air Force photos.

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Executive Summary

This report recommends a future aircraft inventory for the Air Force as required by the 2018 National Defense Authorization Act (see Appendix C). The report also proposes a force planning construct that would require the Air Force to size and shape its future force structure to sustain strategic deterrence, defend the U.S. homeland, and be prepared to defeat major acts of aggression by China and Russia as part of the Joint Force. These recommendations are focused on creating a future aircraft inventory that would be more lethal, resilient, and better able to operate in contested and highly contested environments compared to today's force.[1] This recommended future inventory would be modestly larger than today's force, as would be expected by a shift toward preparing to deter and defeat great power aggression rather than conducting counter- terrorism operations and defeating lesser regional aggressors.

Today, approximately 17 percent of the Air Force's bomber and fighter inventory consists of stealth aircraft that are capable of maneuvering freely in contested areas created by modern surface-to-air and air-to-air threats. In the recommended future force, approximately 68 percent of the Air Force's fighters and bombers would be stealth aircraft. The future force would also have a more balanced mix of short-range combat aircraft with small payloads and long-range penetrating bombers with large payloads. In 2019, approximately 79 percent of the Air Force's total potential daily conventional munitions delivery capacity is provided by fighters that have less than 1,000 nm unrefueled combat radius. Only the 16 stealth B-2 primary mission aircraft inventory (PMAI) in the Air Force's bomber force are capable of

1 For the purposes of this report, in permissive air environments, U.S. air forces can conduct operations nearly unimpeded by enemy forces. In contested air environments, threats pose episodic to near continuous challenges from a single axis to U.S. operations in the air. Communications, sensing, and other operations through the electromagnetic spectrum (EMS) are also degraded in contested environments. In highly contested environments, U.S. air forces must contend with near-continuous or continuous threats from multiple axes and operating domains. The highly contested environment is created by dense, overlapping advanced air-to-air and surface-to-air threats that are highly mobile and use measures such as passive sensors and camouflage to avoid detection. Communications, sensing, and other operations in the EMS could be severely degraded and locally denied in highly contested environments.

striking over long ranges and into contested environments.[2] In contrast, the recommended future force would have a little over 400 PMAI long-range combat aircraft that could penetrate highly contested environments and deliver large quantities of weapons. This would substantially increase the number of targets the Air Force could attack nearly simultaneously over the large areas covered by Chinese and Russian anti-access and area-denial (A2/AD) threats.

This report recommends that the Air Force develop and field a family of capabilities to maintain America's air superiority advantage as well as a multi-domain system-of-systems to provide airborne battle management and command and control (BMC2) to joint air forces conducting dispersed operations over large areas. Needed future capabilities include a Penetrating Counter Air (PCA) aircraft that has greater range, mission endurance, and larger payload capacity than contemporary fighter aircraft. The PCA aircraft would be capable of conducting stand-in (penetrating) electronic warfare missions to help suppress threats and create the degree of air superiority required for other penetrating aircraft and weapons to survive and perform their missions.

The recommended future aircraft inventory would support these combat forces with a larger, modernized force of air refueling aircraft. In addition to the KC-46A aircraft that are now joining the force, the future tanker inventory could include smaller unmanned platforms or theater tankers that could operate from more airfields than KC-46As and KC-135Rs and penetrate for some distance into lower-risk areas of contested environments. These capabilities would improve the Air Force's ability to air refuel joint air forces operating from highly dispersed postures in the Indo-Pacific region and Europe.

CSBA's Study Methodology

CSBA conducted independent research and led workshops and a wargame to evaluate major trends in the security environment, emerging threats, maturing technologies, and new operating concepts that should inform the development of the Air Force's future force. Three workshops conducted at the classified level tasked strategists; defense planners; and technology, aircraft design, and operational experts to assess changes to concepts for major Air Force mission areas. Each workshop culminated in a mini-wargame that played scenarios for major conflicts with China and Russia to stress potential operating concepts and capabilities. The scenarios were set in the year 2035 to enable assessments of technologies and capabilities that could join the force by that time.

Candidate concepts and capabilities were further assessed during a week-long classified wargame led by CSBA. The wargame was an interactive exercise that pitted teams representing the future forces of China and Russia against teams of planners and operators from

2 The Air Force defines Primary Mission Aircraft Inventory as "aircraft assigned against a unit . . . for the performance of its wartime mission." U.S. Air Force, "Aerospace Vehicle Programming, Assignment, Distribution, Accounting, and Termination," Air Force Instruction 16-402, May 30, 2013, Air Combat Command Supplement Certified Current October 31, 2018, p. 37.

the U.S. defense community. Navy, Marine Corps, and Army players contributed to the development of insights on future U.S. multi-domain operations. The wargame culminated in a Strategic Choices Exercise that tasked four teams with assessing how quickly the Air Force may be able to develop the recommended future force given different funding profiles over a ten-year period (FY 2020–2029). Their choices were compared to determine common priorities, how well they supported their concepts for future warfare, and decisions that were driven primarily by budget factors.

These activities were supplemented by insights from previous CSBA wargames and independent analyses. Combined, they formed the basis for the recommendations in this report. The report recommends that the Air Force should develop and field this future force over the next fifteen to twenty years instead of completing it by 2030. Attempting to significantly increase the size of the Air Force's aircraft inventory to reach an objective force by 2030 would require it to procure primarily aircraft that are in production now or are about to enter production. This could reduce funding to develop new weapon systems and create significant gaps in capabilities that would be needed beyond 2030. Nonetheless, this report recommends an aircraft inventory for 2030, as required by the 2018 National Defense Authorization Act (NDAA). Instead of a recommended end state, however, the 2030 inventory is a waypoint on the path toward the force of 2035 and beyond.

Report Organization

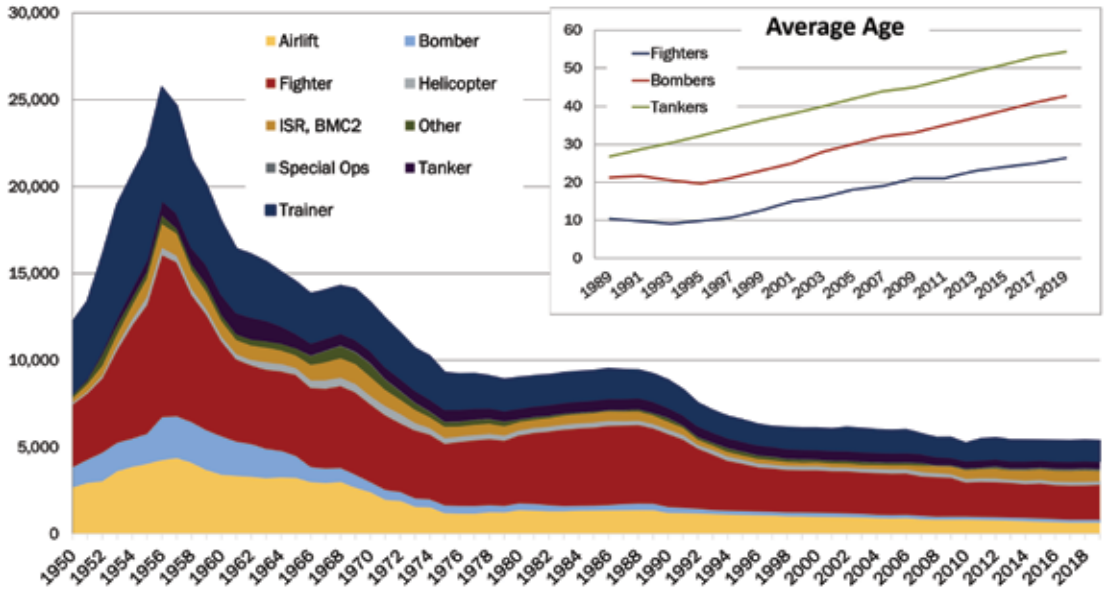
This report is organized into seven chapters. Chapter 1 summarizes key force planning assumptions and resource trends that have shaped the Air Force's aircraft inventory since the end of the Cold War. These assumptions and trends provide context for assessing changes in the size and capacity of the Service's aircraft inventory. Chapter 2 assesses major shifts in the security environment that should inform requirements for the Air Force's future force structure. Chapter 3 recommends a force planning construct for the Air Force. Chapters 4 and 5 summarize insights on concepts and capabilities for future Air Force counterair and global strike operations, respectively. Chapter 6 assesses operating concepts, capabilities, and aircraft inventories for sustaining strategic deterrence, defending the homeland against air and missile threats, and global mobility operations. Chapter 7 concludes with a summary of the recommendations.

Key Insights on the Air Force's Current Aircraft Inventory

A Smaller and Older Force

The Air Force currently has 269 operational aircraft squadrons, including squadrons of unmanned remotely piloted aircraft (RPA) for reconnaissance and light strike. The Air Force uses squadron equivalents as its basic unit to describe its force structure.[3] Except for its mobility air forces, each of these squadrons has a certain number of PMAI aircraft that are resourced to perform the unit's assigned missions. The Air Force's 55 fighter squadron equivalents are roughly half the number of fighter squadrons it had 30 years ago (see Figure 1). Although the Air Force has the largest bomber force in the world, it is smaller than the force it maintained during most of the Cold War, and the emergence of advanced integrated air defense systems (IADS) have diminished its ability to strike globally. Similarly, the Air Force's air refueling tanker force is the smallest and oldest it has ever operated. According to the United States Transportation Command, the combination of high average age and high levels of sustained demand for air refueling support is reaching a breakpoint.[4]

FIGURE 1: AIR FORCE AIRCRAFT INVENTORY TRENDS



3 Secretary of the Air Force for Public Affairs, "Operational Squadrons Key to 'Air Force We Need'," *Air Force News Service*, September 5, 2018, available at https://www.af.mil/News/Article-Display/Article/1621129/operational-squadrons-key-to-air-force-we-need.

4 "We already know the convergence of an aging air refueling fleet with protracted KC-46 production puts the Joint Force's ability to effectively execute war plans at risk . . . Day-to-day, high levels of air refueling fleet utilization are approaching a point that challenges the total force to sustain current levels of support." General Darren McDew, testimony to the HASC Seapower and Projection Forces Subcommittee, March 8, 2018, as quoted by Jason Sherman, "DOD Launches New Mobility Capability and Requirements Study to Influence FY-20 POM," *Inside Defense*, March 15, 2018.

The desire to cut the defense budget to realize a post-Cold War peace dividend formed much of the rationale behind Department of Defense (DoD) decisions to reduce the size of its forces and cancel or cut short programs to recapitalize and modernize aging weapon systems in the 1990s. Higher defense budgets and the allocation of additional funding to the Air Force following the September 11, 2001, terrorist attacks on the United States did not translate to major increases in its aircraft procurement. The Air Force did, however, expand its inventory of RPAs and modified many of its existing aircraft to support overseas contingency operations (OCO).[5] Although useful for combating terrorism, few of the RPAs procured by the Air Force during this period are suitable for operations in contested or highly contested environments. Moreover, cuts to the size of the Air Force's aircraft inventory continued well into the 2000s. As a result, the overall size of the Air Force's aircraft inventory has reached a historic low, and elements of its aircraft inventory have reached average ages that are at historic highs.

A Force that Has Failed to Keep Pace

After the Cold War, DoD shifted its force planning priorities from deterring a Soviet military invasion of Western Europe toward conducting two major regional conflicts (MRC) that closely resembled the 1991 Operation Desert Storm campaign against Iraq. The concept of operations that underpinned U.S. responses to these MRCs assumed U.S. forces could deploy to secure theater bases located close to a regional aggressor, quickly achieve air superiority, and possess superiority in precision strike and other capabilities. These and other optimistic assumptions helped DoD rationalize reductions to the size of its air forces and forego next-generation aircraft acquisition programs. The last true recapitalization and modernization of the Air Force's combat, air refueling, manned intelligence, surveillance, and reconnaissance (ISR), and BMC2 aircraft inventories occurred in the late 1970s and 1980s.

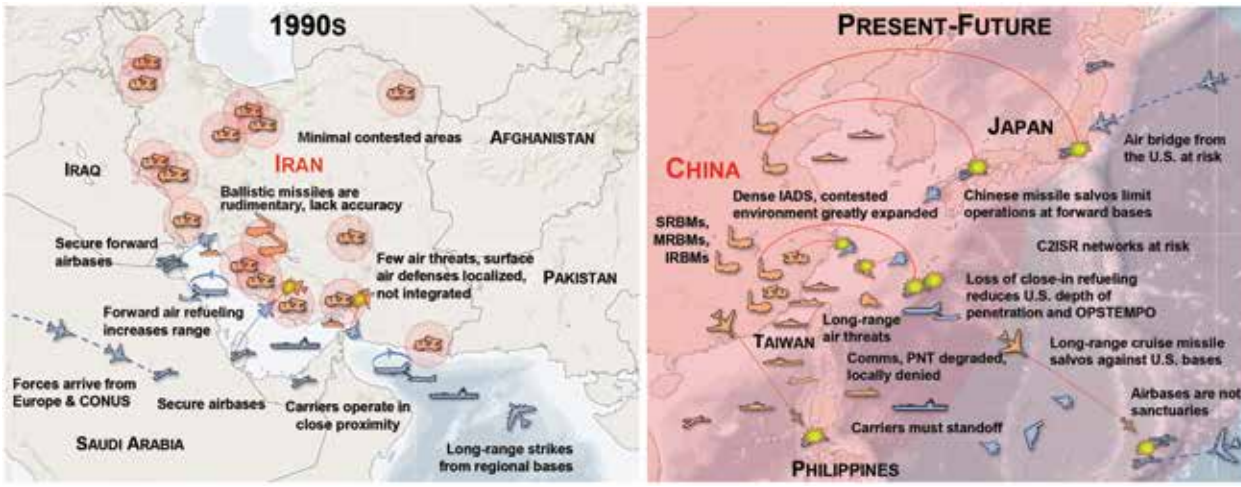
Although reasonable in the 1990s, DoD force planning assumptions and operating concepts lagged behind the evolving threat environment. China and Russia have closely assessed how the United States and other developed countries conducted major conventional military operations since the end of the Cold War. The 1991 Gulf War demonstrated that the United States had successfully operationalized precision strike, stealth, and information technologies for the conduct of warfare. China and Russia have since developed multi-domain A2/AD complexes to support their revisionist national objectives. China's A2/AD complex includes overlapping active and passive air and missile defenses, early warning and target-tracking sensors, low-observable cruise missiles, sophisticated conventional ballistic missiles, increasingly advanced combat aircraft, growing fleets of unmanned aerial vehicles (UAV), and, in the near-future,

5 For example, the Air Force procured 29 MQ-9 RPAs for $561.45 million or $19.36 million per aircraft. See Department of the Air Force, "Aircraft Procurement Vol-1," in *Department of Defense Fiscal Year (FY) 2019 Budget Estimates* (Washington, DC: DoD, February 2018). The Air Force has procured more than 1,000 SNIPER targeting pods to enhance the ability of legacy aircraft like the A-10, F-15, F-16, B-1, and B-52H to conduct close air support.

hypersonic weapons.[6] China's A2/AD "umbrellas" not only cover strategic locations in the East and South China Seas, but also allow the People's Liberation Army (PLA) to hold targets at risk throughout the Western Pacific. Russia's A2/AD systems located in Kaliningrad, its Western Military District, and in Belarus form a protective umbrella over much of the Baltic Sea region. A similar network based in Russia's Southern Military District envelopes the Black Sea region. These A2/AD complexes complement China and Russia's other "home team" advantages over U.S. forces that must deploy from the United States to deter or defeat Chinese or Russian aggression in areas located close to their borders.

To address these challenges, DoD should continue its shift toward using realistic assumptions for great power conflict to assess its future capability and force capacity requirements. For the Air Force, updated planning assumptions should address Chinese and Russian threats to its regional bases, supporting networks, and other challenges that could change how it intends to operate in the future (see Figure 2). These assumptions should be part of a force planning construct for the Air Force.

FIGURE 2: ILLUSTRATING CHANGES IN FORCE PLANNING ASSUMPTIONS



A Recommended Force Planning Construct for the Air Force

DoD uses force planning constructs to describe the concepts of operations (CONOPS); types, number, and frequency of potential major operations; and other assumptions the Services should use as they assess their future force structure and capability requirements. Maturing A2/AD complexes that threaten U.S. forces and bases in both Europe and the Indo-Pacific region compel a break with previous constructs intended for relatively benign operational conditions. At the same time, the Air Force must be prepared to support the nation's strategic

6 Defense Intelligence Agency (DIA), *China Military Power: Modernizing a Force to Fight and Win* (Washington, DC: DIA, 2019), available at http://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/China_Military_Power_FINAL_5MB_20190103.pdf.

deterrence posture and defend the homeland against the attacks of a great power or another opportunistic aggressor. The recommended construct in Table 1 would require the Air Force to organize, train, and equip for strategic deterrence and homeland defense, as well as to defeat major acts of great power aggression against the United States or its allies and friends.

TABLE 1: CANDIDATE FORCE PLANNING CONSTRUCT FOR THE AIR FORCE

Primarily shape and size the force to support these missions and scenarios	Description
Sustain strategic deterrence	• Includes air forces withheld from deployments to support strategic deterrence during great power conflict
Defend the U.S. homeland	• Homeland defense missions include aerospace control and other air operations to deter or counter opportunistic aggression against the homeland; this includes during conflict with one or more great powers • Homeland defense also includes the Air Force's support to civil authorities in the event of a catastrophic event in the U.S. homeland
Conduct operations as part of the Joint Force to defeat major acts of aggression by China and Russia nearly simultaneously	• Example scenario: Conflict to defeat a major Chinese act of aggression in the Indo-Pacific region • Example scenario: Conflict with Russia to defend or secure the sovereignty of an Eastern European NATO ally • A major conflict with China or Russia could be preceded by Chinese or Russian gray zone aggression that escalates to high-end warfare
Then assess the resulting force to determine if it is sufficient to support the following scenarios and mission areas	**Description**
Conflict with a regional aggressor	• Example: Countering aggression by Iran or North Korea
Long-term peacetime competition	• Includes a level of effort over time to deter or counter great power aggression in the gray zone that falls short of outright conflict
Counter-terror operations	• A level of effort to sustain multiple small and widely dispersed counterterror operations over time that require rotational forces

Strategic deterrence. The Air Force maintains three wings of Minuteman III intercontinental ballistic missiles (ICBM), nuclear weapons-capable B-52H and B-2 bombers, and a limited number of dual-capable fighters that can deliver nuclear gravity bombs to meet its nuclear deterrence requirements. These forces are supported by Air Force air refueling tankers, E-4B National Airborne Operations Center (NAOC) aircraft to provide command and control of the nation's nuclear forces in a crisis, and a fleet of rotary wing utility aircraft to support the Air Force's ICBM wings. The recommended force planning construct requires the Air Force to maintain an additive layer of these forces to support strategic deterrence during conflict with one or more great powers. This force would reduce the potential that a great power adversary would seek to escalate a conflict with the United States or take advantage of a U.S. engagement elsewhere to attack the U.S. homeland.

Defend the homeland. The recommended construct requires the Air Force to maintain an additive layer of force structure to defend the U.S. homeland and its overseas territories. In addition to defending U.S. airspace and providing airlift and other capabilities to help manage

the consequences of a major attack or catastrophic incident in the U.S. homeland, future Air Force homeland defense missions could include conducting airborne operations to deter and defend against a limited number of cruise missile attacks during great power conflict.

Defeat great power aggression. The recommended force planning construct requires the Air Force to size and shape its forces to support operations to defeat the campaign strategies of two great power aggressors nearly simultaneously. A Joint Force capable of credibly deterring a second great power seeking to take advantage of the U.S. military's engagement in another theater should include sufficient air forces to support a decisive operation, as opposed to a temporary "holding" action. This is particularly important considering that Chinese and Russian forces conducting combat operations in areas located close to their borders would have significant time and distance advantages over U.S. forces, which must surge from other theaters or their homeland garrisons. These advantages could enable a second aggressor to overwhelm a temporary U.S. holding operation and achieve a *fait accompli* before sufficient U.S. forces could disengage from another conflict and arrive in theater to prevent it. Should this occur, the level of effort needed to then roll-back Chinese or Russian forces that have had time to consolidate and reinforce areas they have occupied could be prohibitive.

The recommended construct assumes that an Air Force inventory that has the capacity to engage against Chinese and Russian high-end aggression would also be capable, in the absence of a major conflict, to support national long-term competition objectives, conduct counter-terror operations, and defeat one or more lesser regional aggressors. It is, however, likely that there will be exceptions to this "lesser-included" assumption for some specialized forces. For instance, long-duration counter-terror operations could create additional requirements for some Air Force special operations capabilities and low-density/high-demand BMC2 systems. For this reason, a force structure sized and shaped for strategic deterrence, homeland defense, and defeating great power aggression should be stress-tested against other potential contingency operations.

Recommendations for the Future Aircraft Inventory

Table 2 summarizes aircraft and squadron equivalents for an aircraft inventory that is aligned with the recommended force planning construct. There is not a specific year associated with the force listed in Table 2 since it includes future weapon systems that are not in production or development in FY 2019. The aircraft inventory in Table 2, which is based on insights developed during the course of this study, is intended to illustrate a future force structure that is consistent with the recommended force planning construct.

TABLE 2: RECOMMENDATIONS FOR THE FUTURE FORCE

	Aircraft	Future Force PMAI	Future Force TAI	Squadron Equivalents
Bombers	B-2	16	20	1
	B-21	206	288	19
	B-52H	44	75	4
	Total	**266**	**383**	**24**
Fighters	F-15E	100	159	5
	F-16	306	572	15
	F-22A	137	186	7
	F-35A	586	908	28
	PCA/P-EA	200	282	10
	Total	**1,329**	**2,107**	**65**

	Aircraft	Future Force PMAI	Future Force TAI	Squadron Equivalents
ISR, Light Strike	MM-UAS	214	291	35
	MQ-X	50	68	8
	Total	**264**	**359**	**43**
ISR and BMC2	P-ISR	116	120	23
	RQ-4	15	16	3
	RC-135	15	22	3
	ABMS	16	21	4
	Total	**162**	**179**	**33**
Refueling	KC-46A equivalents + Future Tanker	568	630	58
	Total	**568**	**630**	**58**

This future force would have a total of 266 PMAI bombers and 1,329 PMAI fighters, which translates to 24 bomber and 65 fighter squadron equivalents. Converted to total aircraft inventory (TAI), the future force would have 383 bombers, assuming B-2 bombers remain in the inventory, and 2,107 fighters.[7] It should be noted that the tanker aircraft listed in Table 2 are a mix of KC-46As and a future tanker employed by teams during CSBA's wargames. The KC-46A program will acquire a total of 179 aircraft, after which the Air Force could procure a manned, unmanned, or optionally manned tanker to continue its tanker force recapitalization. In any case, the 630 TAI air refueling aircraft in Table 2 is about 38 percent larger than the Air Force's current force.

The mix of capabilities in Table 2 would be a major departure from the Air Force's current aircraft inventory. The preponderance of the Air Force's combat, ISR, and BMC2 aircraft cannot penetrate and persist in the contested and highly contested environments that would characterize major engagements against China or Russia in the future. This shortfall would dramatically hinder the Air Force's ability to conduct multi-domain operations. The inventory in Table 2, which should be complemented by the development of new operating concepts for global strike, close air support, counterair, electronic warfare, and other operations that span the spectrum of conflict, would shift the Air Force's future force structure toward a mix that is better capable of deterring and defeating great power aggression.

7 CSBA assumed PMAI to TAI ratios for an ABMS, MM-UAS, and P-ISR would be the same as ratios used today for the Air Force's E-3 AWACS, MQ-9 Reaper, and RQ-4 forces respectively. Since the ABMS, P-ISR, and MM-UAS are concepts without fully defined requirements, their actual PMAI to TAI conversion ratios may be different, particularly for an ABMS multi-domain system-of-systems. TAI includes aircraft assigned to a unit for the performance of it missions; aircraft authorized for performance of its missions; backup aircraft that are "authorized over and above the PAA to allow for scheduled and unscheduled depot level maintenance, modifications, inspections and repairs, and certain other mitigating circumstances without reduction of aircraft available for the assigned mission;" and attrition reserve aircraft that are "required to replace anticipated losses of PAI due to peacetime accidents or wartime attrition." U.S. Air Force, "Aerospace Vehicle Programming, Assignment, Distribution, Accounting, and Termination," pp. 9–10.

Recommendations for the Air Force's 2030 Aircraft Inventory

Table 3 summarizes recommendations for the Air Force's 2030 aircraft inventory that would place it on a trajectory to the future force. Recommendations to accelerate or initiate some new Air Force acquisition programs are informed by the maturity of needed technologies and the potential capacity of the defense industrial base, not by projections of funding that may be available to the Air Force. Table 3 includes a projected baseline inventory for 2030 that is based on unclassified information provided by the Air Force, congressional testimony, and other DoD and non-DoD sources.[8]

TABLE 3: SUMMARY OF FY 2030 AIRCRAFT INVENTORY RECOMMENDATIONS

Aircraft		FY 2019 TAI Actual	CSBA FY 2030 TAI Projection	FY 2030 TAI Recommendation	Comments on FY 2030 Recommendations
Bombers	B-52H	75	75	75	Maintain at current TAI levels
	B-1B	62	42	42	Assumes the Air Force begins to retire B-1Bs as B-21s join the force
	B-2	20	20	20	Maintain at current TAI levels
	B-21	0	38	55	Accelerate procurement
	Total	**157**	**175**	**192**	
Fighters	A-10	281	208	208	Retain 6 squadrons as planned, do not develop a specialized CAS replacement
	F-16	935	625	625	Divest as planned as F-35As join the force
	F-15C/D	234	0	0	Retire in 2020s
	F-15E	218	218	218	Sustain and modernize as needed
	F-22A	186	186	186	Sustain and modernize as needed
	F-35A	171	762	911	Accelerate procurement to 70 per year
	PCA/P-EA	0	0	50	Develop and procure as quickly as possible
	Total	**2,025**	**1,999**	**2198**	
ISR, Light Strike	MQ-9	252	252	252	Begin to replace in 2030s with a new Multi-Mission UAS
	MQ-X	0	0	40	Develop and procure a new penetrating UCAS
	Total	**252**	**252**	**292**	
ISR and BMC2	U-2	30	30	30	Maintain at current TAI levels
	RQ-4	34	34	34	
	RC-135	22	22	22	
	E-3	31	31	31	Develop ABMS and begin to procure in the early 2030s
	E-8	16	0	0	
	ABMS	0	0	0	
	Total	**133**	**117**	**117**	
Tankers	KC-10	59	0	0	Retire as planned as KC-46A join the force
	KC-135	398	341	341	
	KC-46A	Initial deliveries	179	179	Procure as planned
	Follow-on	0	0	?	Develop and procure to minimize gap following KC-46A production
	Total	**457+**	**520**	**520+**	

8 In several instances, CSBA made assumptions for the 2030 baseline about projected acquisition timing, rates, and retirements of aircraft using best available sources. For instance, Table 3 assumes the Air Force will procure the F-35A at an approximate rate of 50 per year, which is consistent with DoD's *2018 Annual Aviation Inventory and Funding Plan*, which projected the Air Force will procure 250 F-35A from FY 2018 to FY 2022. "Specifically, the Air Force plans to procure 250 F-35As from FY 2018 to FY 2022." DoD, *Annual Aviation Inventory and Funding Plan Fiscal Years 2019–2048* (Washington, DC: DoD, March 2018), p. 7. Actual F-35A procurements requested in DoD's future budget submissions may be higher or lower.

Recommendations for the 2030 Bomber Force

B-21 Raider. To ensure it will have the capacity needed to conduct large-scale strike operations in contested and highly contested environments, the Air Force should rebalance its combat forces in favor of long-range, penetrating bombers. The Air Force's planned force of 100 TAI B-21s could fall short of the penetrating strike capacity needed for a single major high-end great power conflict. Assuming annual B-21 production can ramp up to 10 to 20 aircraft per year by the late 2020s, a total of 55 TAI B-21s could be in the force by 2030.

B-2 Spirit. The B-2 is the U.S. military's only aircraft capable of operating over very long ranges and penetrating deep into contested environments until the B-21 is operational. It is also the best means of delivering large weapons by air needed to defeat very hard and deeply buried targets located in contested areas. The Air Force should sustain and modernize its B-2 force as necessary until approximately 2040.

B-52H. The Air Force should sustain its current force of 75 TAI B-52H bombers as planned. The B-52H will be the backbone of the bomber leg of the nuclear triad until B-21s join the force and are certified as nuclear capable. Continued modernization may be needed to ensure the B-52 remains part of the Air Force's family of capabilities for global strike well into the future.

B-1B. The Air Force should gradually retire its B-1Bs as new B-21s join the force. While proven to be highly capable in operations since the end of the Cold War, the B-1B will not be able to penetrate future contested or highly contested environments, and unlike the B-52H, it does not presently have the capability to carry weapons externally. B-1B retirements should be scheduled to avoid increasing the Air Force's shortfall in long-range strike capacity.

Recommendations for the 2030 Fighter Force

The Air Force's fighter force predominately consists of non-stealth aircraft that were originally designed and delivered in the 1990s or earlier. Non-stealth A-10s, F-15C/Ds, F-15Es, and F-16s constitute about 97 percent of the Air Force's current PMAI fighter force. Production of the 5th generation F-22A ceased at 187 aircraft, far short of the Air Force's original requirement of 750 aircraft. The combination of aging forces and lack of modernization programs caused a gap in the Air Force's ability to operate in contested environments. The following recommendations would help place the Air Force on a vector toward the recommended future force.

A-10 Thunderbolt II. The Air Force should retain 208 TAI A-10s as planned until they begin to be replaced in the early 2030s.[9] Since nearly all of its future precision-enabled combat aircraft will be capable of providing close air support to friendly forces, the Air Force should

9 "Current plans include A-10 fleet restructure to six combat coded squadrons in FY21, but to retain those remaining squadrons until the recapitalization by F-35As in the early 2030s." DoD, *Annual Aviation Inventory and Funding Plan Fiscal Years 2019–2048*, p. 7.

not develop a future replacement for the A-10 that would be limited to operations in permissive environments.

F-16 Falcon. The majority of F-16 fighters the Air Force is retiring are from squadrons that are converting to F-35As. The Air Force should retire its oldest F-16s first, sustaining its more capable F-16s through 2030 to maintain required force capacity.

F-35A Lightning II. Designed to replace the F-16 and A-10 force, the F-35A program has been beset by a number of well-known growing pains but appears to have turned the corner. The latest low-rate initial production (LRIP) F-35A unit purchase price was $89.2 million, and future procurements may reach $80 million per aircraft by 2020.[10] To accelerate the fielding of the future force, the Air Force should increase its F-35A procurement to at least 70 per year. This could also help reduce overlap with the production of the B-21, as well as the development and procurement of other Air Force next-generation aircraft and weapons.

F-15E Strike Eagle. Produced between 1987 and 2004, Strike Eagles are the Air Force's newest F-15 fighter aircraft. The Air Force should sustain and modernize its F-15E force through 2030. F-15Es will need a service life extension program in the 2020s if they are to remain in the force past 2030.

F-15C/D Eagle. Due to DoD's decision to truncate F-22 procurement, F-15C/D air superiority fighters have remained in the active force longer than originally planned. Due to the F-15C/D's limited remaining operational life, the Air Force should continue with its plan to retire them in the 2020s. It should also develop and begin to field a family of capabilities that will provide the Joint Force with the degree of air superiority needed to conduct operations in contested and highly contested environments.

F-15X. The Air Force could procure new F-15X fighters to replace some or all of its aging F-15C/D fighters in the 2020s. While F-15Xs are more capable "4th generation-plus" aircraft, they would not be able to operate in future contested and highly contested environments. Moreover, funding for their procurement could reduce resources available to develop other capabilities in the recommended future force. The Air Force should instead consider replacing some retiring F-15C/Ds with modified F-35As as a bridge to its future air superiority family of capabilities.

F-22A Raptor. The Air Force should sustain and continue to modernize its F-22A force at least through FY 2030. The F-22A will remain DoD's most effective counterair fighter until future penetrating counterair aircraft join the force.

10 According to a statement by the F-35 Joint Program Office, "We are committed to reducing costs, and confident the final negotiated LRIP 12 aircraft unit prices will be less than LRIP 11, and enable us to deliver on our goal of an $80 million F-35A by 2020." Ben Werner, "Pentagon Awards $6 Billion Contract Modification to Keep F-35 Production Rolling," *USNI News,* November 15, 2018, available at https://news.usni.org/2018/11/14/pentagon-awards-6-billion-contract-modification-keep-f-35-production-rolling.

Penetrating Counter Air/Penetrating Electronic Attack (P-EA). The PCA/P-EA should be an advanced aircraft capable of operating freely in contested and highly contested environments from significant ranges to perform timely air-to-air and suppression of enemy air defenses/destruction of enemy air defenses (SEAD/DEAD) operations. As part of a family of capabilities for counterair that includes other platforms, sensors, and advanced weapons, the PCA/P-EA aircraft would help degrade area-denial threats and reduce risk for other penetrating platforms and weapons. Similar to the B-21 program, maximizing the use of mature technologies and possibly components and mission systems developed for other advanced platforms could reduce the time and cost of fielding a multi-mission PCA/P-EA aircraft.

Recommendations for the Air Force's 2030 ISR/Light Attack Inventory

MQ-9. The Air Force has divested all of its MQ-1 Predator aircraft and increased the size of its MQ-9 force to support 60 combat air patrols. The MQ-9 force should be sustained through 2030 to help meet continued high operational demand for airborne ISR assets. The Air Force should also assess the potential for using modified MQ-9 to support homeland defense and theater airbase defense missions.

Multi-Mission UAS. This report uses the term "Multi-Mission UAS" (MM-UAS) as a proxy for a follow-on to DoD's current RPAs that can perform a variety of combat and combat support missions in permissive environments and possibly at the low end of contested environments. A future force of MM-UAS could support "mesh" communication networks that extend into contested environments; air-to-surface strikes; homeland defense; and ISR, electronic warfare, and other missions if appropriately equipped. If based on existing technologies or an upgraded variant of a current UAS, an MM-UAS could be quickly acquired.

Future MQ-X. Teams participating in CSBA's workshops and wargame have identified a pressing need for a future penetrating unmanned combat aerial vehicle (UCAV) that could conduct strike, electronic attack, counterair, and other combat missions as part of a family of systems or teamed with manned aircraft. The Air Force should build on previous UCAV developmental programs to initiate development of an MQ-X UCAV that can penetrate and persist in contested environments as soon as possible.[11]

Recommendations for the Air Force's 2030 BMC2 Inventory

Developing a multi-domain BMC2 force capable of supporting operations in future contested environments should be one of the Air Force's highest priorities. The Air Force's BMC2 aircraft are based on 1950s-era airframes that are increasingly difficult to sustain. The Air Force is upgrading to E-3G configuration seven E-3B/C Airborne Warning and Control System (AWACS) aircraft that it planned to retire. This will help sustain its BMC2 capacity in the

11 For instance, the Air Force could leverage technologies developed by the Navy's Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) developmental program and follow-on MQ-25 program.

near-term as it develops an Advanced Battle Management System (ABMS) that will operate in permissive, contested, and highly contested environments. The ABMS will support the ground moving target indicator (GMTI) and airborne moving target indicator (AMTI) missions, allowing the Air Force to retire its E-8 Joint Surveillance and Target Attack Radar System (JSTARS) force.

E-3 AWACS. The Air Force should retain, sustain, and modernize the E-3 AWACS force through 2030 as planned. It should also complete an analysis of alternatives for the Advanced Battle Management System and develop and field a material solution before the E-3 reaches its projected end of service life in the mid-2030s.[12]

E-8C JSTARS. The E-8C cannot survive in contested environments, and it cannot be significantly modified to increase its survivability.[13] The Air Force should retire its JSTARS force by the mid-2020s at a pace that ensures it will not cause a gap in needed BMC2 and GMTI capacity.

Advanced Battle Management System. In 2030 or shortly thereafter, the Air Force should begin fielding an ABMS that provides the Joint Force with BMC2, AMTI, and GMTI in all threat environments. Similar to Air Force capability development initiatives for counterair and electronic warfare, the ABMS should be a system-of-systems of multi-domain AMTI/GMTI sensors and multi-domain battle management capabilities, not an aircraft recapitalization program. It should also include autonomous machine-machine systems and capabilities to fuse information from sensors operating in all domains.

Recommendations for the Air Force's 2030 ISR Inventory

The Air Force's inventory of unmanned ISR systems experienced tremendous growth to meet operational requirements following the terrorist attacks on the United States in September 2001. The non-stealth RQ-4 Global Hawk and MQ-9 ISR/light strike RPA are in high demand in multiple theaters. The RC-135 Rivet Joint strategic reconnaissance aircraft is an extensively modified capability that first joined the force in the 1960s. Similar to the MQ-9, RQ-4, and E-8 JSTARS, the RC-135 is a permissive environment only capability. The following recommendations are intended to shift the Air Force's ISR force toward a future mix for operations in contested environments, while sustaining the capacity needed to support near-term operational demands.

12 Major Quincy Boles, U.S. Air Force, "ACC ABMS AoA Information to Industry," PowerPoint briefing to industry on August 2, 2018.

13 "The recapitalization of the current JSTARS platform is not viable in future contested environments, putting the Battle Management Command and Control and Ground Moving Target Indicator missions at risk in a peer engagement." Lt Gen Jerry Harris Jr. and Ms. Susan Thornton, "Presentation to the House Armed Services Committee Subcommittee on Tactical Air and Land Forces," March 15, 2018, pp. 2–3, available at https://docs.house.gov/meetings/AS/AS25/20180315/107979/HHRG-115-AS25-Wstate-HarrisJ-20180315.pdf.

RQ-4 Global Hawk and U-2. The Air Force should sustain and modernize its RQ-4 and U-2 inventories as necessary through 2030. Earlier retirement of either aircraft would increase DoD's shortfall in strategic surveillance capacity and not make maximum use of their remaining service lives.

RC-135. The Air Force should retain, sustain, and modernize its RC-135 force as needed through at least 2030. A 2008 RC-135 Air Force Fleet Viability Board determined, "Despite the fleet average airframe age of 44 years and total of 38,000 flight hours as of the end of FY2007, the RC-135 should be able to continue to meet the Combatant Commanders' needs through at least 2040."[14]

Future penetrating ISR. Persistent, penetrating airborne ISR would be critical to the air interdiction of highly mobile armored vehicles and other land forces invading a North Atlantic Treaty Organization (NATO) ally. It would also be necessary to find, fix, track, and provide shooters with cues to attack mobile surface-to-air missiles (SAM), missile launchers, and other high-end Chinese and Russian A2/AD systems. Fielding one or more unmanned P-ISR variants should be one of the Air Force's highest priorities for its future global awareness force.

Recommendations for the Air Force's 2030 Air Refueling Force

The size of the Air Force's tanker force is at a historic low, and its average age of about 53 years is at a historic high. The ability to conduct aerial refueling in permissive environments and at the low end of contested environments will be essential to future joint multi-domain operations. Similar to other elements of the future force, Air Force tankers should also be capable of operating from a more dispersed basing posture compared today's KC-135 and KC-10 force. The most significant challenge, however, may be providing air refueling to support highly distributed joint air operations in Europe and over the vast dimensions of the Indo-Pacific theater during great power conflict. A shortfall in the number of air refueling booms the Air Force can generate to support these operations may be more significant than fuel offload capacity shortfalls. The following recommendations address these challenges.

KC-135. The Air Force should coordinate retirement of the KC-135 force with the procurement of replacement aircraft to ensure its shortfall in air refueling capacity does not increase.

KC-10. The Air Force had planned to begin retirement of its KC-10s in 2019 and complete their retirement in 2024. To avoid increasing its current gap in air refueling capacity, the Air

14 The same Congressional Research Service (CRS) report quoted here identified concerns over the ability of the U.S. command, control, intelligence, surveillance, and reconnaissance (C2ISR) industrial base to sustain this fleet: "Another potential oversight issue is the ability of the nation's industrial base to sustain the legacy C2ISR aircraft force. A potential problem with sustaining a fleet of aircraft of their age is that the industrial base that developed and produced these aircraft may no longer possess the capability to manufacture and supply parts in the necessary quantities to affordably keep these aircraft flying." Jeffrey Nelson, *U.S. Command and Control and Intelligence, Surveillance, and Reconnaissance Aircraft* (Washington, DC: CRS, July 15, 2015), pp. 26–34, 49.

Force should delay the KC-10's retirement by two or more years to ensure a sufficient number of KC-46A tankers have joined the force.

KC-46A. The Air Force should procure the KC-46A through 2027 as planned to replace its aging KC-135R/T and KC-10. It should also plan to upgrade the KC-46A to perform as a communications and situational awareness node to support multi-domain operations, as well as to provide it with some countermeasures against area-denial threats.[15]

Future air refueling tanker/follow-on to the KC-46A. The ability to air refuel in permissive environments and in the low end of the contested environment will be essential to future joint operations. This study considered future unmanned and optionally manned designs with survivability enhancements that could allow the Air Force to conduct refueling operations in the low end of contested environments and it considered a lightweight, highly efficient tanker that could increase the future tanker force's fuel offload potential. These concepts should be considered by the Air Force's Analysis of Alternatives for a future tanker that could enter production shortly before the currently planned 179 KC-46As are procured.

Recommendations for the 2030 Strategic and Tactical Airlift Force

C-17A and C-5M. The strategic airlift force may be the Air Force's healthiest force. The Service procured its final C-17 in September 2013 and has completed extensive modifications to its C-5s. The Air Force should sustain and modernize this force as necessary through 2030.

Tactical airlift. The Air Force should sustain and modernize its theater airlift forces as necessary through 2030. Future requirements for theater airlift will be dependent on multiple factors such as emerging joint doctrine and the future composition of the Army and other elements of the Joint Force. The Air Force should assess how these changes could impact its tactical airlift requirements.

Other Recommendations

Combat search and rescue (CSAR), special operations, and training aircraft inventories. The Air Force should retain some number of legacy HH-60G aircraft in the short term and acquire the Combat Rescue Helicopter to ensure it will have sufficient capacity to support current and future conflicts. The Air Force should also continue its planned recapitalization and modernization of its special operations and training aircraft inventories.

Future airbase defenses. It is highly likely that theater bases critical to future U.S. air operations will be subject to kinetic and non-kinetic attacks during a major conflict with China or Russia. Given the magnitude of the threat, the Air Force should assume greater

15 Air Mobility Command (AMC) priorities for its mobility aircraft include improving their on-board and off-board situational awareness and ability to defend against threats. Air Mobility Command, "AMC Capability Gaps," slide provided to CSBA on October 13, 2018 by Headquarters, Air Mobility Command.

responsibility for defending its theater airbases. The Air Force may need additional funding and end strength for this change to its roles-and-missions responsibilities.

U.S. munitions and missile industrial base. DoD inventories of preferred munitions have long lacked the resiliency needed to support high-intensity conflicts of long duration. Increases in the size of the Air Force's aircraft inventory recommended by this report should be accompanied by increased investments in the weapons they could expend in times of crisis. Absent these investments, current munitions shortfalls would persist or even grow, eroding the Air Force's ability to perform its mission.

Opportunities for reduced Air Force operation and sustainment costs. There has been significant growth in Air Force operations and maintenance expenditures, which reached a historic high of $63.7 billion in FY 2011 in constant year 2019 dollars. Part of this growth was the result of increased costs to operate and support an aging force. Retiring old aircraft that are increasingly expensive to maintain and would require expensive life extension programs could help free resources needed for aircraft modernization and recapitalization programs. Maintaining a balanced high-low force mix of manned and unmanned systems in the near and mid-term could also reduce the Air Force's operations and support expenditures.

In conclusion, the return of great power competition has closed the window of time where the Air Force could accept increased risk by forgoing major investments to rebuild and modernize its aircraft inventory. Creating a more range-balanced, survivable, and lethal force will require the commitment of the Department of Defense and Congressional leadership to significant increases in the Air Force's annual budget. It will take years of increased funding to rebuild its air forces following nearly three decades of an advanced aircraft procurement holiday. Further delays to this rebuilding would increase the risk that America's air forces will not keep pace with the military advances of China and Russia.

CHAPTER 1

Air Force Force Structure and Resource Trends

Chapter 1 summarizes key force planning assumptions and resource trends that have shaped the Air Force's aircraft inventory since the end of the Cold War. These assumptions and trends provide context for assessing changes in the size and capacity of the Service's aircraft inventory that are needed to prepare for great power competition and conflict. The chapter begins with a short overview of aircraft now in the Air Force's inventory. It then describes major force planning assumptions that have had a lasting influence on Air Force aircraft modernization and recapitalization decisions since the Cold War. A final section summarizes force structure and budgetary trends, including historical acquisition funding profiles for the Air Force, that highlight how these assumptions impacted the Service's aircraft inventory.

Overview of the Current Air Force

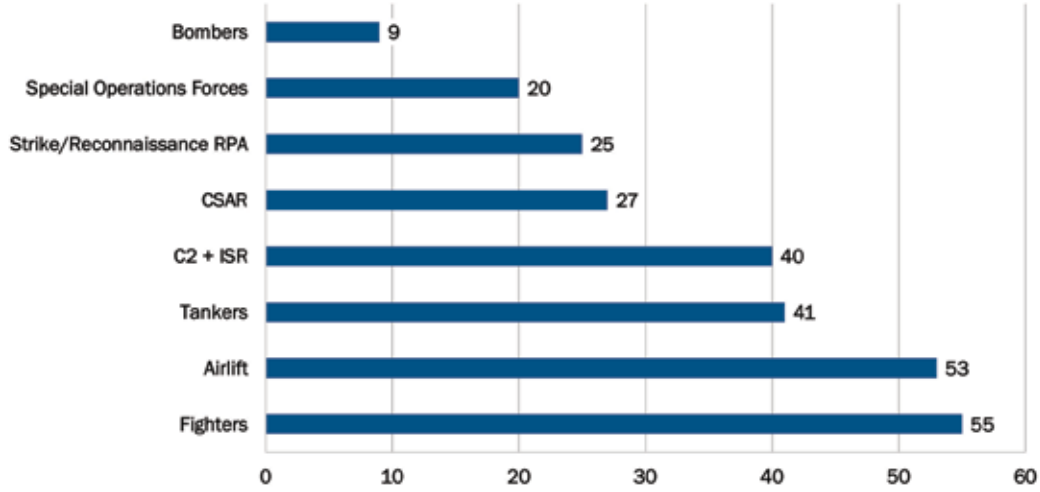
This section provides an overview of three major segments of the Air Force's aircraft inventory: its combat air forces (CAF), mobility air forces (MAF), and special operations forces (SOF).[16] The CAF includes Air Force fighters, bombers, ISR aircraft, BMC2 platforms, and CSAR fixed-wing and rotary-wing aircraft. The MAF consists of air refueling tankers, strategic airlift platforms, and smaller, shorter-range tactical airlift aircraft. The SOF aircraft inventory includes modified tactical lift systems and the CV-22 tilt-rotor aircraft.

According to the Air Force, it now has 270 operational aircraft squadrons, including squadrons of unmanned remotely piloted aircraft for reconnaissance and light strike (see Figure 3).

16 The final data as of February 2018 from the Air Force's FY 2019 President's Budget Force Structure Data Management (FSDM) database was the primary data used to determine TAI and PMAI aircraft inventories for FY 2019 in all tables in this section unless otherwise noted. The source of this unclassified data is from ABIDES, provided to CSBA by the Air Force. Aircraft age data was determined by unclassified data supplied to CSBA from the Air Force's Reliability and Maintainability Information System (REMIS), current as of November 2018.

The Air Force uses squadrons as its basic unit to "generate effects in the battlespace" and to explain its current and future force structure requirements.[17] Except for its mobility air forces, each of the Air Force aircraft squadrons have a certain number of PMAI aircraft that are resourced to perform the unit's assigned missions.

FIGURE 3: CURRENT AIR FORCE OPERATIONAL AIRCRAFT SQUADRONS



The Air Force uses TAI aircraft to define the size of its strategic airlift, tactical airlift, air refueling, and global air mobility squadrons. This report uses the same squadron nomenclature and inventory accounting rules as the Air Force to propose a future aircraft inventory for the Service's CAF, MAF, and other forces as required by the 2018 NDAA.

Overview of the Air Force's Combat Air Force

The fighter force. The Air Combat Command (ACC) is an Air Force Major Command that is responsible for providing fighters, bombers, and other CAF capabilities for air and space superiority, global integrated ISR, global strike, and command and control operations.[18] ACC now has 55 fighter squadron "equivalents" of 21 PMAI aircraft each. This equates to 2,026 TAI and

17 Secretary of the Air Force for Public Affairs, "Operational Squadrons Key to 'Air Force We Need'," *Air Force News Service*, September 5, 2018, available at https://www.af.mil/News/Article-Display/Article/1621129/operational-squadrons-key-to-air-force-we-need.

18 U.S. Air Force, *Air Force Future Operating Concept: A View of the Air Force In 2035* (Washington, DC: U.S. Air Force, September 2015), available at https://www.af.mil/Portals/1/images/airpower/AFFOC.pdf.

1,145 PMAI fighters in FY 2019 (see Table 4).[19] ACC also provides electronic combat aircraft, personnel recovery, and combat support forces to U.S. combatant commanders.[20]

TABLE 4: THE AIR FORCE'S CURRENT FIGHTER AIRCRAFT INVENTORY

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
F-35A	2011–Present	171	48	2.9
F-22A	2001–2012	186	123	11.2
F-15E	1987–2004	218	138	26.7
F-15C/D	1979–1989	235	156	34.6
F-16 all blocks*	1984–1994	935	509	28.0
A-10C	1979–1984	281	171	37.6
Total		**2,026**	**1,145**	**26.4 years**

*The Air Force has procured about 325 "lower block" F-16s (Blocks 25, 30, 32), and about 614 "higher block" (Blocks 40, 42, 50, and 52) F-16s with upgraded capabilities. Many lower block aircraft have already been retired and remaining lower block F-16s will need to be retired soon due to service life issues.

Due to force structure cuts and a lack of recapitalization programs since the end of the Cold War, the Air Force's fighter force is roughly half the size it was thirty years ago and has reached an unprecedented average age of over 26 years. It is also increasingly expensive to operate, in part due to the need to fund fighter service life extension programs and upgrade them to the extent possible to address emerging threats.

The bomber force. Today's bomber force consists of 75 TAI non-stealth B-52H, 62 TAI non-stealth B-1B, and 20 TAI stealth B-2 bombers (see Table 5).[21] The B-52H performs both conventional and nuclear missions and is the only U.S. bomber now capable of carrying nuclear air-launched cruise missiles (ALCM). Operational since the early 1960s, the Air Force projects its B-52H bombers will remain in the operational force for decades.[22] The B-1B is a conventional-only, long-range bomber capable of supersonic flight. The Air Force has proposed retiring the B-1 as the B-21, its new bomber, joins the force in the mid-2020s. The

19 Except for the F-35A and F-16, the final data as of February 2018 from the Air Force's FY 2019 President's Budget Force Structure Data Management (FSDM) database were the primary data used to determine TAI and PMAI aircraft inventories for FY 2019 in Table 4. The F-35A and F-16 inventory data were provided by the Air Combat Command's Force Structure Branch (ACC/A8BF), current as of January 3, 2019. Average ages were calculated in November 2018. "Squadron equivalents" is a term used by the Air Force to describe its force structure. The FY 2018 NDAA requires the Air Force to maintain (a minimum of) 1,970 fighter TAI and 1,145 PMAI. In addition, the Air Force must maintain 171 PMAI A-10s.

20 Air Force Association, "USAF Almanac 2018," *Air Force Magazine,* June 2018, p. 60.

21 Bomber inventory data were provided by ACC/A8BF, current as of January 3, 2019.

22 With planned life extension modifications, the B-52 could be in service through 2050, which will be far longer than any previous Air Force aircraft. See Secretary of the Air Force Public Affairs, "Air Force Outlines Future of Bomber Force," *Air Force News Service*, February 12, 2018, available at https://www.afgsc.af.mil/News/Article-Display/Article/1439155/air-force-outlines-future-of-bomber-force/.

B-2 is a long-range, stealth bomber capable of conducting conventional and nuclear strikes in contested environments.[23]

TABLE 5: THE AIR FORCE'S BOMBER AIRCRAFT INVENTORY

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
B-52H	1960–1962	75	44	57.0
B-1B	1986–1988	62	36	31.3
B-2	1989–1997	20	16	24.4
Total		157	96	42.7 years

Although the Air Force has the largest bomber force in the world, the fielding of advanced integrated air defense systems has diminished its ability to strike globally with precision. Today, only 13 percent of the U.S. bomber force—20 B-2 bombers—is capable of penetrating contested threat environments. Non-stealth B-1s and B-52Hs would likely be limited to conducting standoff operations during a conflict with Chinese or Russian forces. The bomber force has an average age that is second only to the air refueling forces the Air Force fielded in the same timeframe as the B-52H. The Air Force intends to procure at least 100 B-21 bombers that will be capable of operating in contested and highly contested environments.[24]

Air Force BMC2 and ISR forces. The Air Force's manned BMC2 aircraft are derived from Boeing-707 airframes or the C-135 Stratolifter, a derivative of the Boeing prototype that was the basis for the B-707.[25] The Air Force's unmanned ISR aircraft are more recent acquisitions procured primarily to support overseas counter-terror missions and other overseas contingency operations in multiple theaters. All manned and unmanned aircraft listed in Table 6 are only capable of operating in permissive environments.[26]

23 For the purposes of this report, in contested environments threats pose episodic to near continuous challenges from a single axis to U.S. operations in the air. In highly contested environments, U.S. military aircraft must contend with near-continuous or continuous threats from multiple axes. Figure 7 illustrates threats to air operations in permissive, contested, and highly contested environments.

24 Jeremiah Gertler, *Air Force B-21 Raider Long-Range Strike Bomber* (Washington, DC: Congressional Research Service, June 7, 2017), p. 1, available at https://fas.org/sgp/crs/weapons/R44463.pdf.

25 Robert S. Hopkins III, *Boeing KC-135 Stratotanker: More Than Just a Tanker* (Leicester, England: Midland Publishing Limited, 1997). The first Boeing prototype was the Boeing 367-80 (or Dash 80) and derivatives led to the B-717 (KC-135s) and the B-707.

26 The inventory data in Table 6 were provided by ACC/A8BF, current as of January 3, 2019. Due to their small numbers, the Air Force's OC-135, WC-135, WC-130, RC-26, MQ-1, MC-12, E9, E-11, and E-4 are not included in Table 6.

TABLE 6: THE AIR FORCE'S CURRENT BMC2 AND ISR AIRCRAFT INVENTORIES

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
E-3 AWACS	1976–1983	31	23	39.1
E-8 JSTARS	1996–2005	16	11	18.0 (average age since the aircraft was modified, not airframe age)
RC-135	1962–1965	22	17	55.2
U-2	1968–1988	30	24	35.7
RQ-4	2007–2018	34	31	7.3
MQ-9	2004–2018	252	197	5.1
	Total	**99 manned 286 unmanned**	**75 manned 228 unmanned**	**38.7 years manned 5.3 years unmanned**

The Air Force has released its Next Generation ISR Dominance Flight Plan to guide the development of next-generation ISR and BMC2 capabilities that will be needed for operations in future highly contested environments. The plan's unclassified summary indicates that the Air Force will shift away from manpower-intensive ISR and BMC2 platforms that are only capable of operating in permissive environments toward a human-machine teaming approach with aircraft that will be more resilient, persistent, and survivable.[27]

Air Force Combat Search and Rescue forces. The Air Force organizes, trains, and equips a force for airborne CSAR. A lethal, agile, and credible CSAR force is a means to prevent enemies from exploiting the propaganda value of captured U.S. personnel. Current Air Force investments include recapitalization of aging aircraft; modernization of the fixed-wing, rotary- wing, ground, and survival components; and enhancing lethality for hazardous and hostile environments. The Air Force has mostly replaced its aging HC-130P/N aircraft with modified C-130J aircraft and is in the process of recapitalizing its HH-60G "Pave Hawk" combat rescue helicopters with more capable HH-60W aircraft that are derivatives of the combat-proven UH-60 Black Hawk.[28]

27 Dash Jamieson, "Next Generation ISR Dominance Flight Plan Summary," memo, 2018, available at https://www.airuniversity.af.edu/Portals/10/ISR/Documents/HAF_A2/Next-Gen_ISR_Flight_Plan.pdf. Human-machine teaming initiatives generally seek to improve interfaces between systems and humans to increase their combined operations. "The benefits to DoD on focusing on the human-machine system versus the platform are: improved performance, reduced cost of operating and designing platforms, increased adaptability of existing systems to new situations and accelerated adoption. Better human-machine teamwork leads to faster performance of tasks with fewer errors." "Human Machine Teaming," Defense Innovation Marketplace, available at https://defenseinnovationmarketplace.dtic.mil/technology-interchange-meetings/autonomy-tim/human-machine-teaming/.

28 DoD, *Annual Aviation Inventory and Funding Plan*: *Fiscal Years (FY) 2019–2048* (Washington, DC: DoD, March 2018). The inventory data in Table 7 were provided by ACC/A8BF, current as of January 3, 2019.

TABLE 7: THE AIR FORCE'S CURRENT CSAR AIRCRAFT INVENTORY

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
HC-130	1993–2018	30	24	11.4
HH-60	1982–2013	99	73	27.4
	Total	**129**	**97**	**23.6 years**

Overview of the Air Force's Mobility Air Forces

The United States is dependent on the Air Force's airlift and aerial refueling aircraft to project military power. The Air Force's Air Mobility Command is responsible for organizing, training, and equipping mobility air forces that include air refueling aircraft, strategic and tactical airlift, and aeromedical evacuation platforms.[29] AMC also manages the Civil Reserve Air Fleet (CRAF), which consists of aircraft pledged by airlines and other civil air carriers to provide cargo and passenger airlift to DoD in emergencies.

Air refueling aircraft. Since the end of the Cold War, the primary mission of the Air Force's air refueling force has shifted from supporting strategic bomber operations to refueling joint air forces that are deploying and conducting operations in the U.S. homeland and abroad. Air Force tankers provide an "air bridge" that is essential to ensuring U.S. combat and other forces can rapidly deploy to distant theaters. They are also force multipliers that extend the range and mission endurance of combat, ISR, BMC2, and other aircraft in the Joint Force. The Air Force now has 41 squadron equivalents of 11 TAI KC-135R or KC-10 tanker aircraft each (see Table 8).[30] KC-135Rs can refuel military aircraft using a flying boom, or a flexible hose with a drogue attached to it. KC-10 tankers are modified versions of DC-10 aircraft produced for commercial use.

TABLE 8: THE AIR FORCE'S CURRENT TANKER AIRCRAFT INVENTORY

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
KC-135	1958–1964	398	378	57.3
KC-10	1981–1989	59	54	33.9
KC-46A	2019-Future	Number of 2019 deliveries TBD	–	–
	Total	**457+**	**432**	**54.3 years**

29 The U.S. Transportation Command (USTRANSCOM) is a U.S. unified functional command responsible for the transportation, sustainment, and distribution of personnel, equipment and supplies whether it be air, sea, or land. The Air Force's Air Mobility Command, the Navy's Military Sealift Command, and the Army's Surface Deployment and Distribution Command are USTRANSCOM component commands.

30 Due to delays in KC-46A deliveries and the Air Force's decision to not retire KC-10 aircraft starting in FY 2019, the tanker force structure in FY 2018 is used as the baseline in Table 8. Data was provided to CSBA from the Air Force's REMIS, Weapons Systems View, current as of November 2018. Aircraft in Table 8 do not include Air Force Special Operations Command MC-130 tankers and small numbers of other Air Force specialty refueling aircraft.

This fleet of aircraft is the oldest force in the Air Force. According to the United States Transportation Command, the combination of high average age and high operational demand for air refueling aircraft is becoming unsustainable.[31] In January 2019, the Air Force accepted delivery of the first of 179 KC-46A air refueling aircraft that will replace older KC-135Rs and KC-10s.

Strategic airlift. The Air Force's strategic airlift platforms move personnel, cargo, and other material over intercontinental ranges and across theaters. In 2019, the Air Force had a total inventory of 222 C-17 and 52 C-5 strategic airlift aircraft (see Table 9). The C-5 is the largest airlifter in the U.S. military's inventory. The Air Force has completed a comprehensive program to modernize its remaining 52 C-5s.[32] Renamed the "Super Galaxy," the C-5M could be in service until 2040.

TABLE 9: THE AIR FORCE'S CURRENT STRATEGIC AIRLIFT AIRCRAFT INVENTORY

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
C-5	1970–1989	52	44	31.9
C-17	1992–2013	222	180	15.2
	Total	**274**	**232**	**18.4 years**

Tactical airlift. The Air Force's tactical airlift aircraft mainly operate within a particular area or theater of operations. About 94 percent of the Air Force's tactical airlift force consists of C-130H and C-130J aircraft. The force also includes smaller numbers of aircraft that perform specialty missions, such as the WC-130 weather reconnaissance platform and the ski-equipped LC-130 that supports polar operations.[33]

TABLE 10: THE AIR FORCE'S CURRENT TACTICAL AIRLIFT AIRCRAFT INVENTORY

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
C-130J	1999–2018	127	113	8.8
C-130H	1974–1997	173	151	28.7
	Total	**300**	**264**	**20.3 years**

31 "We already know the convergence of an aging air refueling fleet with protracted KC-46 production puts the Joint Force's ability to effectively execute war plans at risk . . . Day-to-day, high levels of air refueling fleet utilization are approaching a point that challenges the total force to sustain current levels of support." General Darren McDew, testimony to the HASC Seapower and Projection Forces Subcommittee, March 8, 2018, as quoted by Jason Sherman, "DOD Launches New Mobility Capability and Requirements Study to Influence FY-20 POM," *Inside Defense*, March 15, 2018.

32 The C-5 Avionics Modernization Program (AMP) and Reliability Enhancement & Re-engining Program (RERP) ran from 2006 to 2018.

33 For the purpose of brevity, Table 10 does not include the WC-130 and small numbers of other Air Force specialized airlift aircraft. Table 10 PMAI inventory data were provided by the Air Force to CSBA from the Air Force's REMIS, Weapons Systems View, current as of November 2018.

Variants of the C-130 Hercules aircraft have been in service with the Air Force since 1956. The Air Force has acquired the latest version of the C-130, the C-130J, to recapitalize its tactical airlift forces. With new engines, new avionics, and about a 30 percent improvement in useable cargo volume, the C-130J is an upgrade over the C-130H aircraft it is replacing.[34]

Air Force Special Operations Aircraft

The Air Force Special Operations Command (AFSOC) provides air mobility, precision strike, ISR, and other capabilities to support U.S. special operations forces deployed globally.[35] The command is upgrading its fleet of AC-130 gunships with modified C-130J aircraft and plans to field 37 AC-130Js by FY 2025. It is also procuring 57 MC-130J aircraft to recapitalize its MC-130 aircraft by FY 2026.[36]

TABLE 11: THE AIR FORCE'S CURRENT SPECIAL OPERATIONS AIRCRAFT INVENTORY

	Years Entered the Force	Total Aircraft Inventory (TAI)	Primary Mission Aircraft Inventory (PMAI)	Average Age in Years
AC-130	1991–2018	38	23	18.9
MC-130	1966–2018	56	43	13.2
EC-130J	1999–2003	7	6	18.4
CV-22	2005–2016	50	38	6.8
	Total	**151**	**110**	**12.5 years**

AFSOC's EC-130J "Commando Solo" aircraft conduct psychological operations, information operations, and provide civil affairs broadcasts in various communications bands. CV-22 Ospreys, a variant of the Marine Corps' tilt-rotor MC-22s, conduct infiltration/exfiltration missions and resupply special operations forces over long ranges.

The Enduring Impact of Post-Cold War Force Planning Assumptions

Force planning priorities and assumptions adopted by DoD after the end of the Cold War had an enduring impact on the size and capabilities mix of the Air Force's aircraft inventory. Many of these priorities and assumptions were intended to prepare the U.S. military to fight two major regional conflicts that closely resembled the 1991 Operation Desert Storm campaign to evict Iraq from Kuwait. DoD's post-Cold War shift from preparing for global conflict with the Soviet Union toward organizing, training, and equipping its forces to defeat conventional

34 DoD, "C-130J Hercules Transport Aircraft (C-130J)," Selected Acquisition Report, December 2017, available at https://www.esd.whs.mil/Portals/54/Documents/FOID/Reading%20Room/Selected_Acquisition_Reports/18-F-1016_DOC_06_AF_C-130J_SAR_Dec_2017.pdf.

35 Air Force Special Operations Command, "Air Force Special Operations Command: About Us," fact sheet, May 9, 2017, available at https://www.afsoc.af.mil/About-Us/Fact-Sheets/Display/Article/162540/air-force-special-operations-command/.

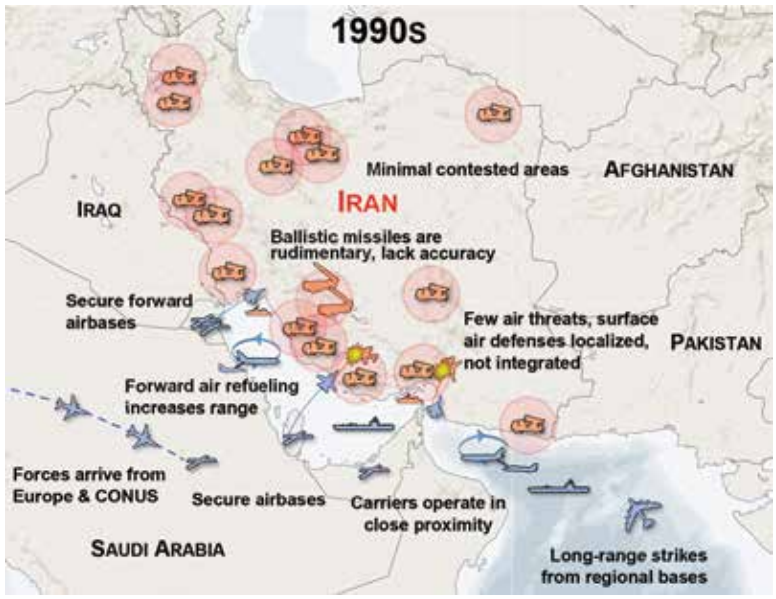
36 DoD, *Annual Aviation Inventory and Funding Plan: Fiscal Years (FY) 2019–2048* (Washington, DC: DoD, March 2018), p. 29.

invasions launched by regional aggressors was largely the product of a "Base Force" strategic review initiated by the Joint Staff in 1988 and the post-Desert Storm Bottom-Up Review (BUR) conducted by the Clinton administration in 1993.[37] These reviews established a template for sizing and shaping DoD force structure based around rapidly halting and then defeating invading mechanized forces in two theaters nearly simultaneously. This template included an overarching CONOPS for MRC scenarios that assumed:

- The U.S. military could deploy unopposed from their garrisons in the United States to theater bases located close to a regional aggressor;
- The low risk of air and missile attacks on theater airbases would allow U.S. air forces to maintain a high tempo of offensive operations;
- U.S. and allied naval forces, including carrier battle groups, would be able to operate close to an enemy's shores at low risk of attack;
- The U.S. military would continue to have an overwhelming advantage in many critical mission areas, including precision strike and electronic warfare;
- U.S. and allied air forces could quickly establish control of the air;
- Air refueling operations could be conducted at low risk close to the battlespace; and
- Enabling U.S. logistics and command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) networks, including space-based systems, would remain secure.

37 The Base Force review also provided guidelines for the "reduction of our Armed Forces without breaking them or reducing their quality." Lorna A. Jaffe, *The Development of the Base Force 1989–1992* (Washington, DC: Chairman of the Joint Chiefs of Staff [CJCS], July 1993), foreword. For a short analysis of the *Bottom-Up Review*, see Mark A. Gunzinger, *Shaping America's Military: Toward a New Force Planning Construct* (Washington, DC: Center for Strategic and Budgetary Assessments, 2013); and Mark Gunzinger, Bryan Clark, David Johnson, and Jesse Sloman, *Force Planning for the Era of Great Power Competition* (Washington, DC: Center for Strategic and Budgetary Assessments, 2017).

FIGURE 4: ILLUSTRATING PERMISSIVE ENVIRONMENT OPERATIONAL ASSUMPTIONS



Similar to Desert Storm, this CONOPS assumed the United States and its allies would have months to deploy a massive force to a theater of operations before launching a decisive combined arms counteroffensive to roll back invading forces and, if necessary, change the regime of an aggressor state.[38]

These planning assumptions underpinned DoD decisions to reduce the size of its forces and truncate programs to procure new, more advanced major weapon systems suitable for projecting power into contested air, sea, space, and cyber environments. To cite one example, during its 1997 Quadrennial Defense Review, DoD decided to end production of the B-2 stealth bomber at 21 aircraft instead of the originally planned force of 132 aircraft. The operating concept justifying this action assumed that a small, "silver bullet" complement of B-2s would be sufficient to conduct initial strike operations against an overmatched regional opponent, by which time U.S. forces could suppress enemy air defenses to the point where stealth bombers would not be needed. Other assumptions, such as the ability to conduct high tempo combat operations from secure theater bases located close to an enemy's borders and air refuel nearly unchallenged by air and missile threats, contributed to decisions to reduce the size of the Air Force's fighter force. The ability to "swing" some air forces from one theater of operations to a second MRC also reduced overall requirements for U.S. military aircraft.[39]

38 The scenarios the 1993 BUR "focused on most closely . . . envisioned aggression by a remilitarized Iraq against Kuwait and Saudi Arabia, and by North Korea against the Republic of Korea." DoD, *Report on the Bottom-Up Review* (Washington, DC: DoD, 1993), p. 14.

39 "Selected high-leverage and mobile intelligence, command and control, and air capabilities would be redeployed from the first MRC to the second as circumstances permitted." DoD, *Report on the Bottom-Up Review*, p. 28.

Although DoD has conducted a number of strategic reviews since the 1990s, many of these and other major planning assumptions adopted in the 1990s continue to influence its force structure and program acquisition decisions. As a result, much of the U.S. military has not kept pace with the evolving security environment and is now equipped with some major weapon systems, including ISR and combat aircraft, that are at risk of being overmatched by emerging Chinese and Russian capabilities. The following section provides a more in-depth assessment of how these planning assumptions influenced the size and characteristics (e.g., average age, survivability, payloads, and range) of the Air Force's aircraft inventory.

U.S. Air Force Force Structure Trends

A Smaller and Older Force

Since the end of the Cold War, the Air Force has funded multiple modifications, upgrades, and service life extension programs (SLEP) to extend the operational longevity and improve the mission performance of its aging aircraft.[40] Fighter aircraft such as the A-10, F-15, and F-16, that were first designed in the 1980s or earlier, have been upgraded to improve their ability to deliver weapons with precision, enhance their survivability against some threats, and increase their interoperability with other Air Force and joint weapon systems. Similarly, upgrades have made the Air Force's B-52H and B-1B bombers more lethal and capable of performing non-traditional missions for bombers such as providing close air support to friendly ground forces with precision.

Combined with the desire to cut the defense budget to realize a post-Cold War "peace dividend," increased weapon system lethality formed part of the rationale behind DoD decisions to truncate or forgo acquisition programs to replace many of the Air Force's 4th generation fighters, older bombers, and other aircraft.[41] For instance, DoD decided to reduce the total number of F-22 fighters it planned to procure "consistent with its much greater capability compared to the F-15." Other factors, including program cost overruns, program delays, and the high unit cost of the F-22, also contributed to this decision.[42] As a result, the overall size of

40 Over the last ten years, the Air Force has also had to correct for structural weaknesses discovered during full-scale fatigue testing of some of its oldest aircraft. Some of the Air Force's aircraft are so old that entire sections of their airframes must be rebuilt to keep them flying.

41 DoD, *Report of the Quadrennial Defense Review* (Washington, DC: DoD, May 1997), p. 45.

42 For an assessment of factors that contributed to the F-22 program's early termination, see Barry Watts, *The F-22 Program in Retrospect* (Washington, DC: Center for Strategic and Budgetary Assessments, December 2009), available at https://csbaonline.org/research/publications/the-f-22-program-in-retrospect.

the Air Force's aircraft inventory has reached a historic low, and elements of its aircraft inventory have reached average ages that are at historic highs (see Figures 5 and 6).[43]

FIGURE 5: AIR FORCE TOTAL AIRCRAFT INVENTORY FY 1950–FY 2019

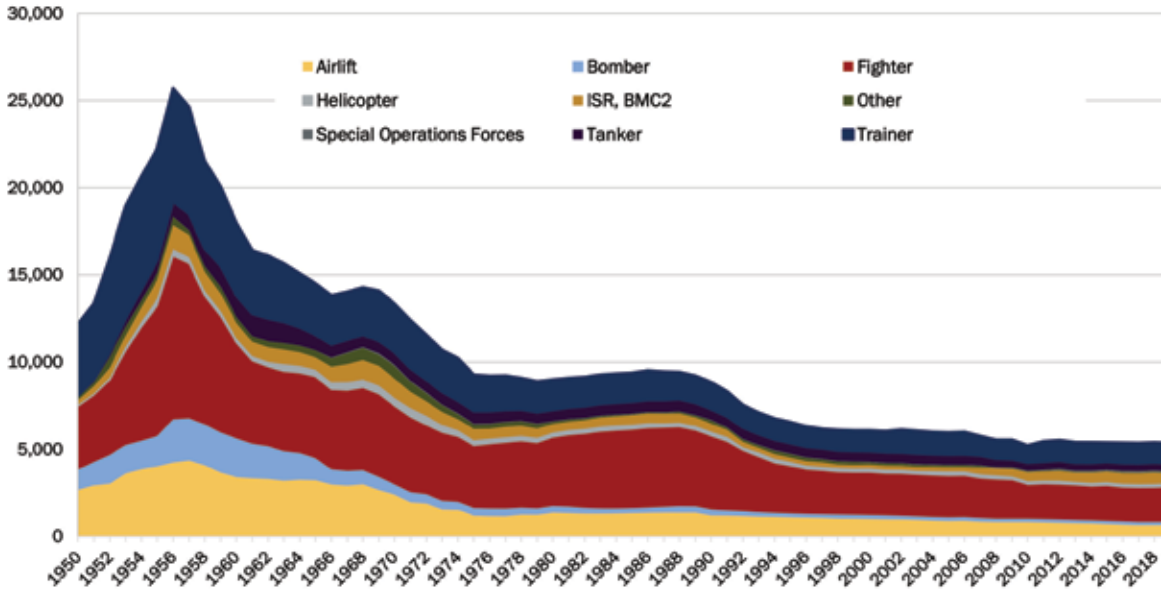
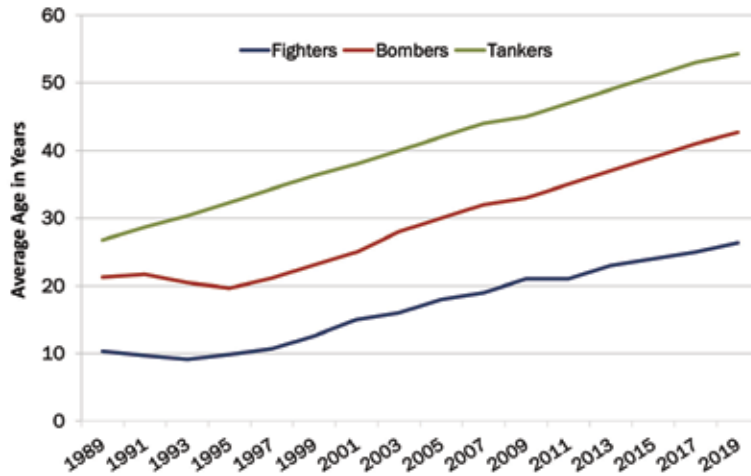


FIGURE 6: AVERAGE AGE OF THE AIR FORCE'S FIGHTER, BOMBER, AND TANKER FORCES



43 CSBA compiled a historical inventory of Air Force aircraft, measuring total aircraft inventory, since 1950. Unless otherwise noted, all subsequent Air Force historical inventory charts and tables in this report are based on a database containing information from James C. Ruehrmund Jr. and Christopher J. Bowie, *Arsenal of Airpower: USAF Aircraft Inventory 1950–2016* (Arlington, VA: Mitchell Institute, February 2018); and unclassified data provided by the Air Force to CSBA. Average aircraft ages in Figure 6 are from U.S. Air Force, *USAF Statistical Digests* (Washington, DC: Comptroller of the Air Force, 1960, 1980, 2000); Air Force Association, "USAF Almanac 2018"; and the Air Force's ABIDES Weapons System View database.

Cuts to the Air Force's aircraft inventory were not limited to the peace dividend years of the 1990s. Since FY 2001, the total number of Air Force aircraft decreased from 6,258 to 5,384.[44] Over this period, the Air Force's fighter force decreased by roughly 21 percent, and its bomber force was cut by 25 percent (see Table 12). The Air Force expected that the air refueling tankers it retired in the 2000s, which mostly consisted of KC-135Es that had considerable service life, readiness, and cost growth issues, would be replaced with new tankers.

TABLE 12: CHANGES IN AIR FORCE FIGHTER, BOMBER, AND TANKER TAI SINCE FY 2001

Aircraft Inventory Category	FY 2001	FY 2019	Aircraft Lost or Gained FY 2001–2019	% Change FY 2001–2019
Fighters	2,576	2,026	-550	-21%
Bombers	208	157	-51	-25%
Tankers	609	457	-152	-25%
BMC2, ISR (including RPAs)	78	385	+307	+394%

From a total inventory perspective, the magnitude of these reductions is masked somewhat by the large number of RPA the Air Force procured since 2001 for ISR and light strike operations in Iraq and Afghanistan, as well as for counter-terror operations globally.

A Permissive Operational Environment Force

It is highly unlikely that further modifications and upgrades will make Air Force aircraft that were designed for the threat environments of the Cold War era capable of operating in future contested or highly contested environments. In other words, there are limits to the benefits that can be realized by upgrading older aircraft or by developing new variants of aircraft that were originally designed decades ago. Except for a small number of stealth F-22s, B-2s, and F-35As that are now in the force, the Air Force's CAF cannot operate in contested environments without the risk of suffering significant and perhaps prohibitive levels of attrition. The Air Force's non-stealth bombers, 4th generation fighters, air refueling tankers, BMC2, and ISR platforms are best suited for operations in permissive environments—and in some cases possibly at the low end of the contested environment.

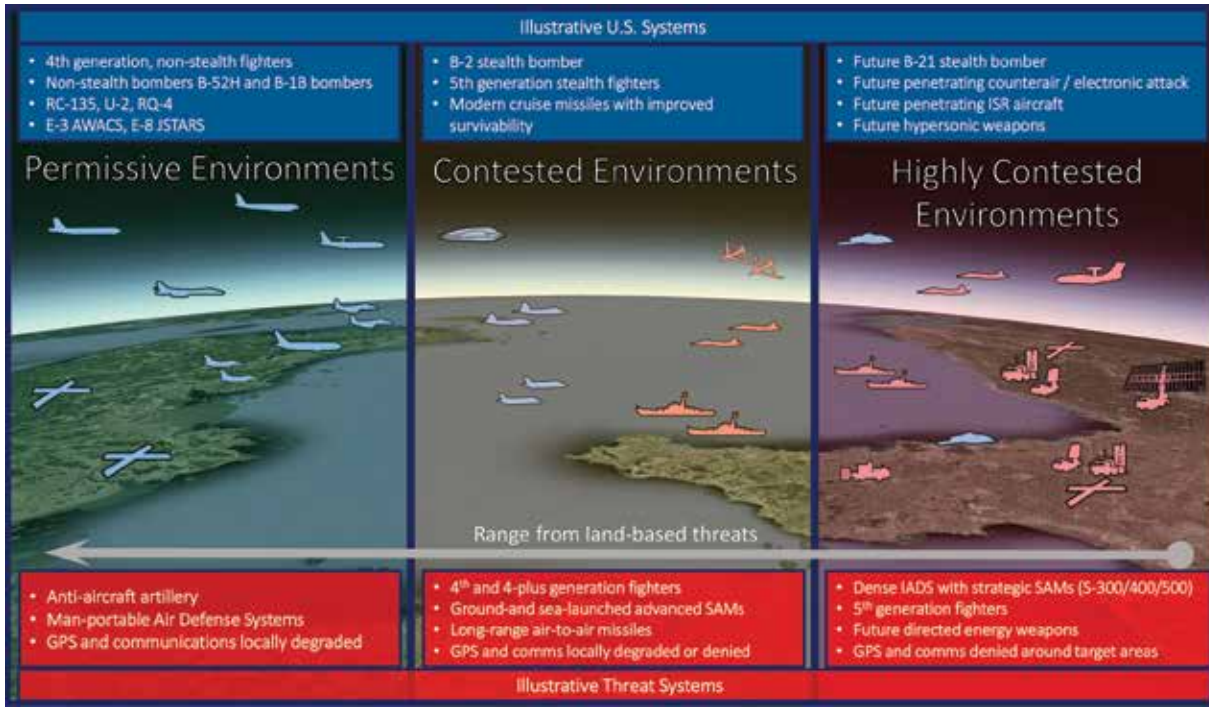
Although DoD has not precisely defined what it means when it uses the terms "permissive," "contested," and "highly contested" environments, for the purposes of this report, they are defined by the kinds of threats that are present (see the red boxes in Figure 7). In permissive environments, U.S. air forces can conduct operations unimpeded or nearly unimpeded by an enemy.[45] In contested environments, enemy airborne threats pose episodic challenges to U.S. aircraft, while surface-to-air threats pose near continuous challenges from a single known

44 Total Aircraft Inventory was derived from unclassified data on the Air Force's ABIDES Weapons System View database provided to CSBA by the Air Force.

45 The use of permissive, contested, and highly contested refers to the aerial environment vice the ground environment. Given the growing range of Chinese and Russian conventional weapons and special forces, it is unlikely there will be many if any truly permissive operating areas on the ground in a theater of conflict.

threat axis and location. In highly contested environments, U.S. military aircraft must contend with unlocated surface-to-air threats from all directions (front, side, and rear). The highly contested environment is created by dense, overlapping advanced surface-to-air systems that are highly mobile and use measures such as passive sensors and camouflage to avoid detection. The lethality, range, density, and geographic dispersion of these systems, combined with modern fighters, electronic warfare aircraft, cyber-attacks, and other threats, create an all-aspect, multi-domain challenge for U.S. aircraft. Chapter 2 provides a more in-depth description of the emerging threat environment.

FIGURE 7: CHARACTERIZING THREAT ENVIRONMENTS FOR FUTURE AIR OPERATIONS

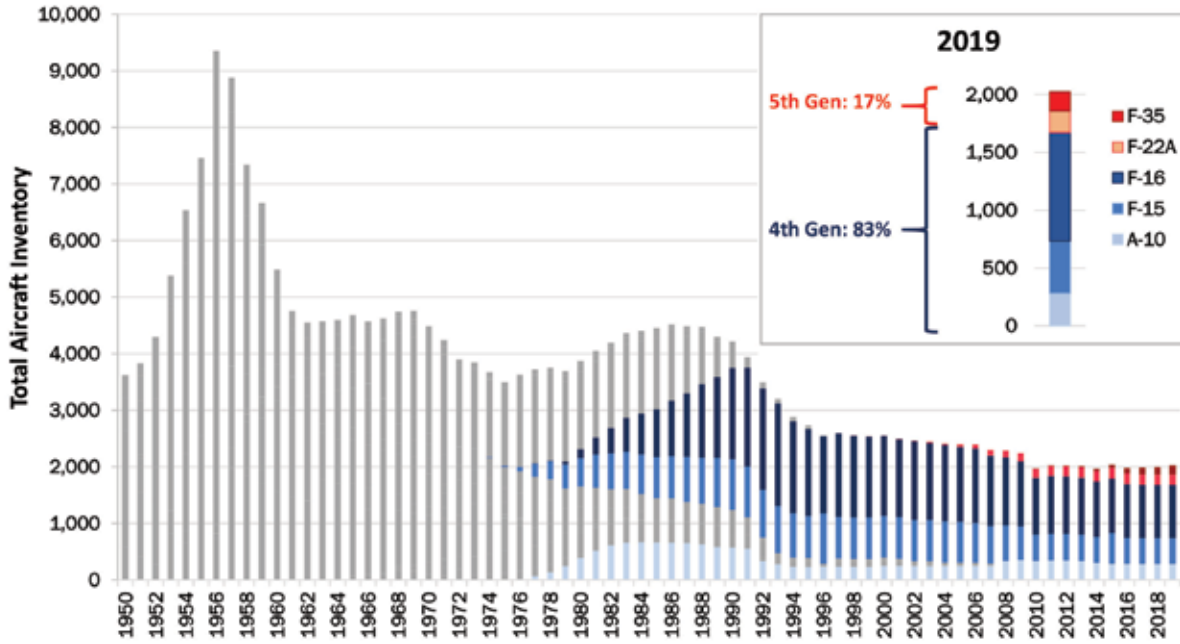


To a large extent, the Air Force's current force mix is the result of optimistic force planning assumptions and an enduring reliance on CONOPS adopted by DoD in the aftermath of the Cold War.[46] Although reasonable in the 1990s, DoD force planning assumptions and operating concepts have lagged behind the evolving threat environment. This was evident in DoD's decision to truncate the Air Force's acquisition of stealth aircraft in the 1990s and 2000s due to a belief that they would not be needed in significant numbers to support operations against

46 While much of the rationale behind the Air Force's inventory is a function of force planning assumptions, economic factors cannot be ignored. Cost growth in procurement programs were a factor that contributed to DoD decisions to buy fewer aircraft. As procurement quantities decreased, fixed costs were spread over a smaller number of aircraft and production learning also decreased. Both factors increased average unit costs, which conspired to further decrease the quantities procured and further raise unit costs. See Russell Rumbaugh, *What We Bought: Defense Procurement from FY01 to FY10* (Washington, DC: Stimson Center, October 2011).

potential regional aggressors or conduct other overseas contingency operations.[47] The preponderance of the Air Force's 2019 fighter force consists of 4th generation, non-stealth aircraft (see Figure 8), and its bomber force has only 20 stealth B-2 bombers.[48] This mix will change as additional F-35A fighters join the force.

FIGURE 8: TRENDS IN THE AIR FORCE'S FIGHTER INVENTORY



Shift Toward Smaller Weapons Payloads and Shorter Ranges

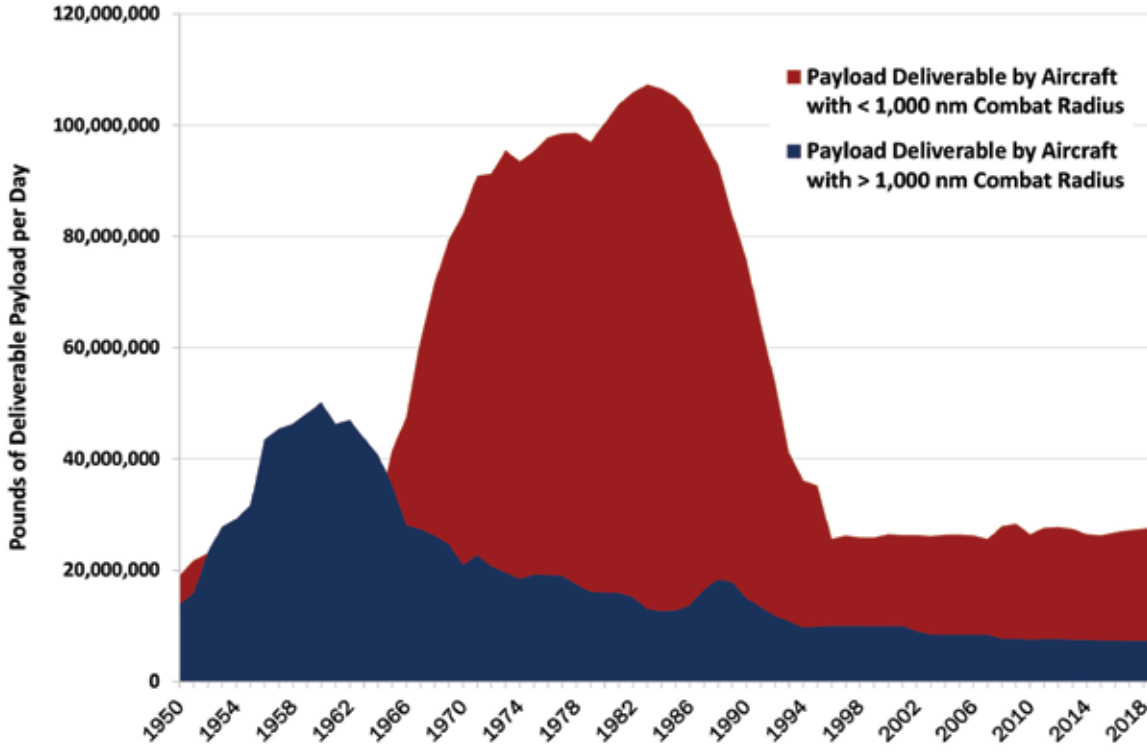
Other decisions helped shift the Air Force's inventories of strike aircraft toward a force mix that predominately consists of short-range platforms that have fighter-sized internal weapons bays. DoD began to downsize its bomber force in the waning years of the Cold War, a trend that continued into the 1990s with the B-2 program's early termination. Both the 1993 Bottom-Up Review and 1997 Quadrennial Defense Review (QDR) assumed the most significant need for large payload bombers would be during the initial weeks of a conflict with a regional aggressor, after which a much larger force of Air Force, Navy, and Marine Corps fighter aircraft could arrive in theater and conduct the preponderance of airstrikes. Today, Air

47 DoD capped procurement of the stealth F-22 air dominance fighter at 187 aircraft instead of the Air Force's original requirement of 381 aircraft.

48 Figure 8 includes the Air Force's A-10 inventory but not its MQ-9 force.

Force combat aircraft with less than 1,000 nm unrefueled combat radius have the potential to deliver 79 percent of its daily strike potential (see Figure 9).[49]

FIGURE 9: TRENDS IN CAF WEAPONS PAYLOAD DELIVERABLE BY RANGE



In summary, many of the Air Force's combat air, ISR, and BMC2 forces consist of aircraft that are too old, too easy to detect, and too dependent on close-in theater airbases and unrestricted air refueling. These force structure characteristics play into the hands of great power competitors with capable A2/AD complexes.

Trends in Air Force Budget and Acquisition Funding

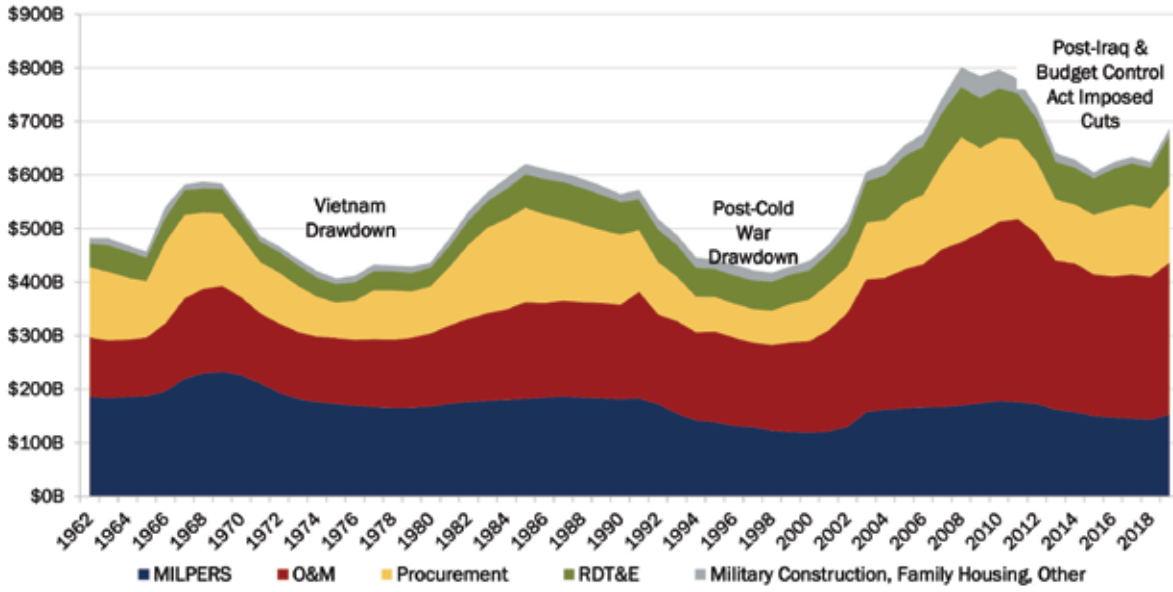
Like most developed countries, the United States usually increases its defense expenditures in times of conflict and reduces it in times of peace. During post-war major defense drawdowns, DoD military personnel spending tends to decrease as its end strength is reduced, and its procurement funding falls as threats that spur the acquisition of new weapon systems recede.

49 Figure 9 assumes that each Air Force aircraft capable of conducting strikes could deliver full payloads of weapons on targets located at its maximum unrefueled combat radius. It also assumes that aircraft with an unrefueled combat radius of less than 1,000 nm can conduct two sorties per day; aircraft with an unrefueled combat radius greater than or equal to 1,000 nm could fly 0.8 sorties per day. F-15C/D air superiority aircraft are not included, but the F-22 force is. The MQ-9 force is also included.

These trends reverse during defense buildups, giving the Services an opportunity to recapitalize and replace their aging capabilities.

The defense spending cycle that began in the early 1990s was no different inasmuch as presidential administrations and Congress sought a post-Cold War peace dividend. It was, however, atypical in terms of how DoD's budget was allocated when its budget eventually rebounded in the 2000s.[50] As Figure 10 shows, operations and maintenance (O&M) spending soared in the 2000s even though DoD's force structure was far smaller than it was in 1990.[51]

FIGURE 10: DEFENSE APPROPRIATIONS FY 1962 TO FY 2019 (TOA IN FY19 DOLLARS)

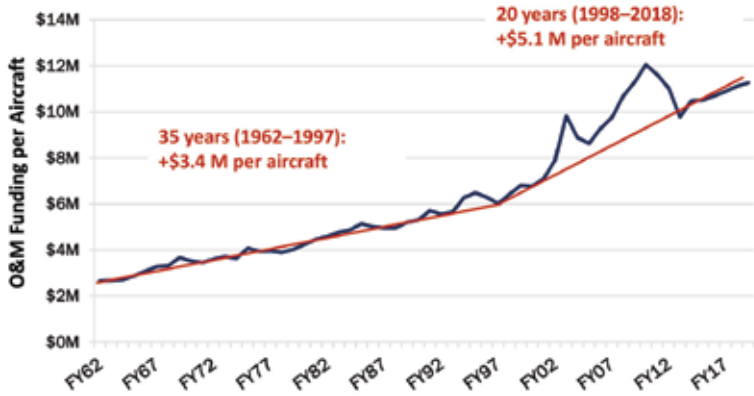


Air Force O&M funding during this period tells a similar story. Normalized by its total aircraft inventory, Air Force O&M spending increased by about $3.4 million per aircraft over the 35-year period between 1962 and 1997. In the 20 years since 1997, the Air Force's O&M cost per aircraft grew by $5.1 million. This accelerated growth was largely due to the increased utilization rate of aircraft supporting overseas contingency operations, the increased cost of maintenance that had been deferred during the defense budget downturn of the 1990s, and the increased maintenance needed to sustain an aging force.

50 Post-Cold War procurement funding provides another contrast from previous drawdowns. From the U.S. withdrawal from Vietnam to its post-war nadir (1973 to 1975), DoD procurement funding fell by about 23 percent. In contrast, procurement funding fell by over 43 percent from the end of the Cold War until it began to rebound in 1998.

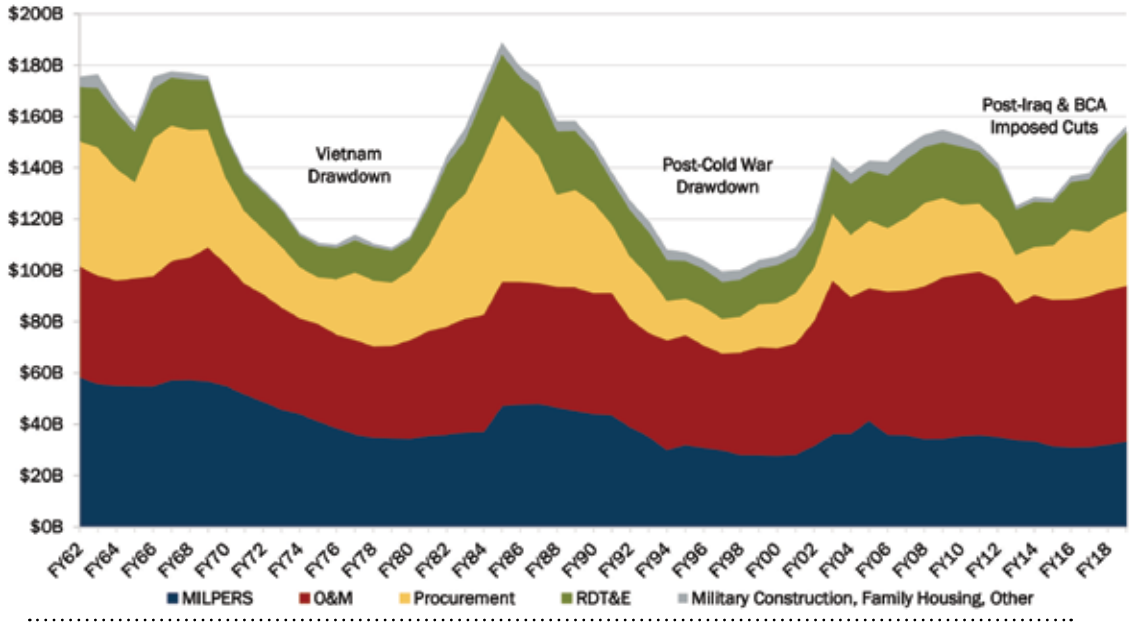
51 Office of the Undersecretary of Defense (Comptroller) [OUSD(C)], *National Defense Budget Estimates for FY 2019, FY 2019 Greenbook* (Washington, DC: DoD, April 2018), Table 6-1, "Department of Defense TOA by Public Law Title (FY 1948 to FY 2019)."

FIGURE 11: TRENDS IN O&M FUNDING PER AIRCRAFT



Procurement spending during the 1990s–2000s defense budget cycle was also atypical. In the 1990s, Air Force procurement funding fell substantially more than in previous defense drawdowns (see Figure 12).[52] After the United States withdrew its forces from Vietnam, Air Force procurement funding fell 23 percent by 1975. By contrast, Air Force procurement funding dropped by 47 percent after the Cold War, reaching its nadir in 1998. This constrained the Air Force's ability to develop and procure next-generation aircraft.

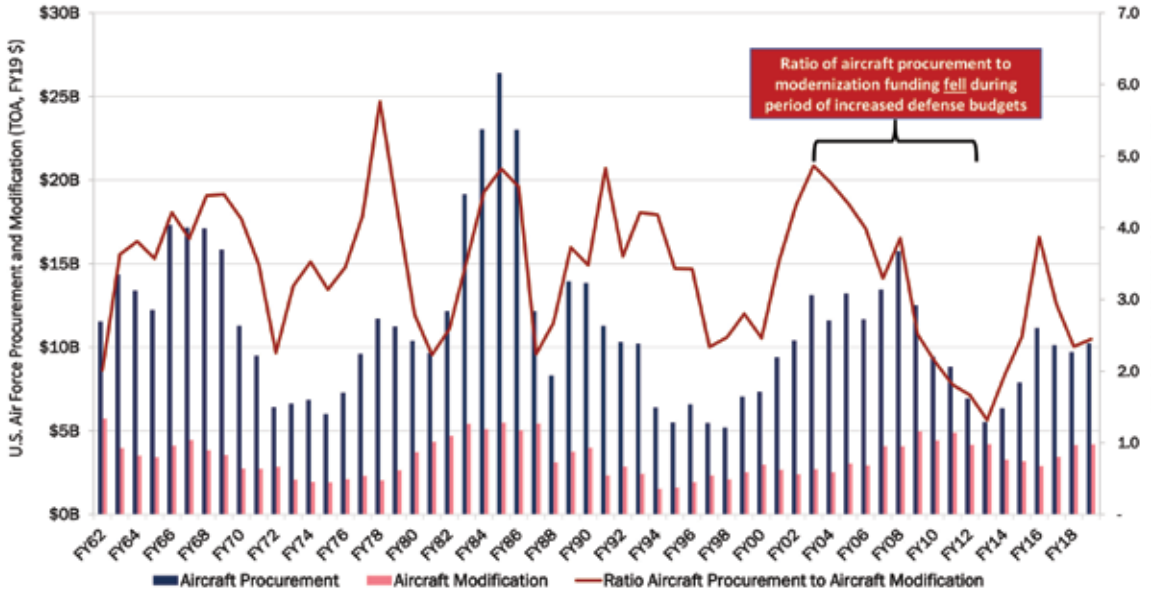
FIGURE 12: AIR FORCE BLUE APPROPRIATIONS FY 1962 TO FY 2019 (TOA, $FY19)



52 Air Force appropriations mask one important detail related to its funding. Roughly 18 percent of the Air Force's budget from 1989 to 2019 was "pass-through" funding. The Air Force has no control over this money—it simply transmits this part of its budget to fund a variety of intelligence community programs. It is important to understand what portion of Air Force appropriations are available to the Air Force. In other words, what portion of the budget is "Blue" funding versus what is pass-through funding. Unless otherwise noted, all references to Air Force funding cover "Blue" funding only. Figures 10, 11, and 12 are based on unclassified data provided to CSBA by the Air Force from its ABIDES database.

The Air Force's fiscal situation improved after Congress increased defense appropriations following the September 2001 terrorist attacks on the United States. Higher defense budgets and the allocation of additional resources to the Air Force did not, however, lead to major new investments to replace its aging aircraft inventory. From one perspective, the relationship between the Air Force's new aircraft procurement funding and its aircraft modification funding during this period more closely resembled what occurred during past funding drawdowns. For the decade after 2001, the ratio of funds spent on procuring new aircraft to those spent modifying existing aircraft *decreased*, as it normally would during a funding downturn (see Figure 13).

FIGURE 13: AIR FORCE AIRCRAFT MODIFICATION AND PROCUREMENT FUNDING TRENDS

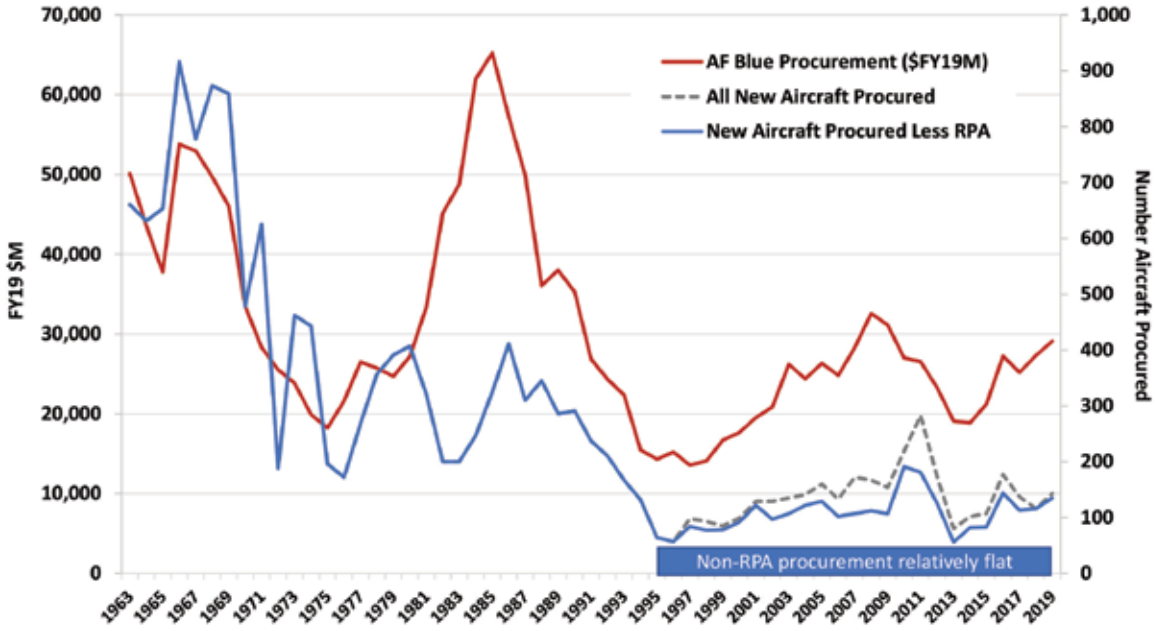


Given operational demands for Air Force forces to support counterinsurgency and counterterrorism operations, this allocation of resources makes sense. To help meet increased demands for persistent ISR and light strike, the Air Force expanded its inventory of RPAs, which were inexpensive to procure relative to new high-end fighters and bombers, and modified many of its existing aircraft.[53] While useful in combating insurgencies and terrorist organizations, few RPAs procured by the Air Force during this period are suitable for operations in future contested or highly contested environments.

53 For example, the Air Force procured 29 MQ-9 RPAs for $561.45 million or $19.36 million per aircraft. See Department of the Air Force, "Aircraft Procurement Vol-1," in *Department of Defense Fiscal Year (FY) 2019 Budget Estimates* (Washington, DC: DoD, February 2018). The Air Force has procured more than 1,000 SNIPER targeting pods to enhance the ability of legacy aircraft like the A-10, F-15, F-16, B-1, and B-52H to conduct close air support.

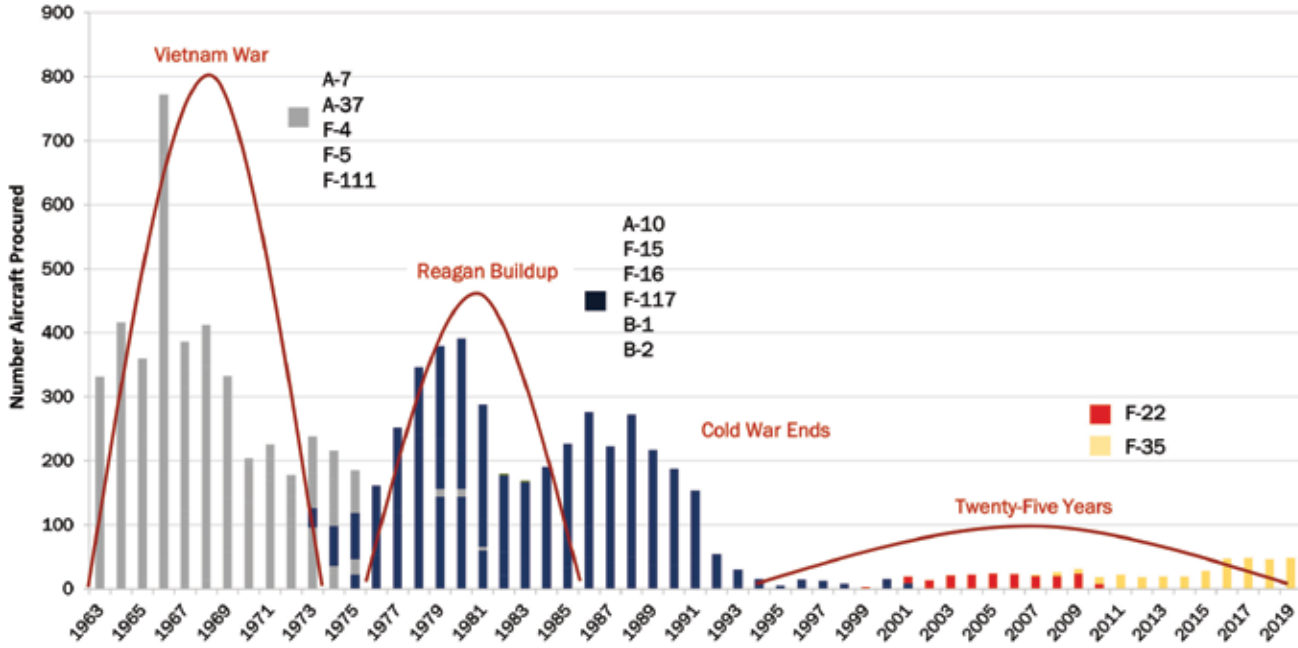
Historically, Air Force procurement spending tends to follow the same trend as the quantity of new aircraft it procures. Air Force new aircraft procurement funding reached a high in the middle of the 1980s and dropped after the Cold War (see Figure 14). This pattern generally held true until the late 1990s, when the Air Force's total procurement spending increased and the number of new aircraft it procured remained flat.

FIGURE 14: TRENDS IN THE AIR FORCE'S TOTAL BLUE PROCUREMENT FUNDING AND AIRCRAFT PROCURED



The preponderance of the Air Force's aircraft procurement funding in the late 1990s and 2000s was allocated toward the F-22A program, buying C-17s and modifying C-5s to recapitalize its strategic airlift force, recapitalizing portions of the tactical airlift force with C-130Js, and expanding the size of unmanned aircraft to meet operational demand for ISR and light strike UAV capacity. With the exception of buying a small, silver bullet F-22 force, the Air Force did not replace its aging combat aircraft. As illustrated by Figure 15, this extended the Air Force's nearly 25-year combat aircraft procurement holiday.

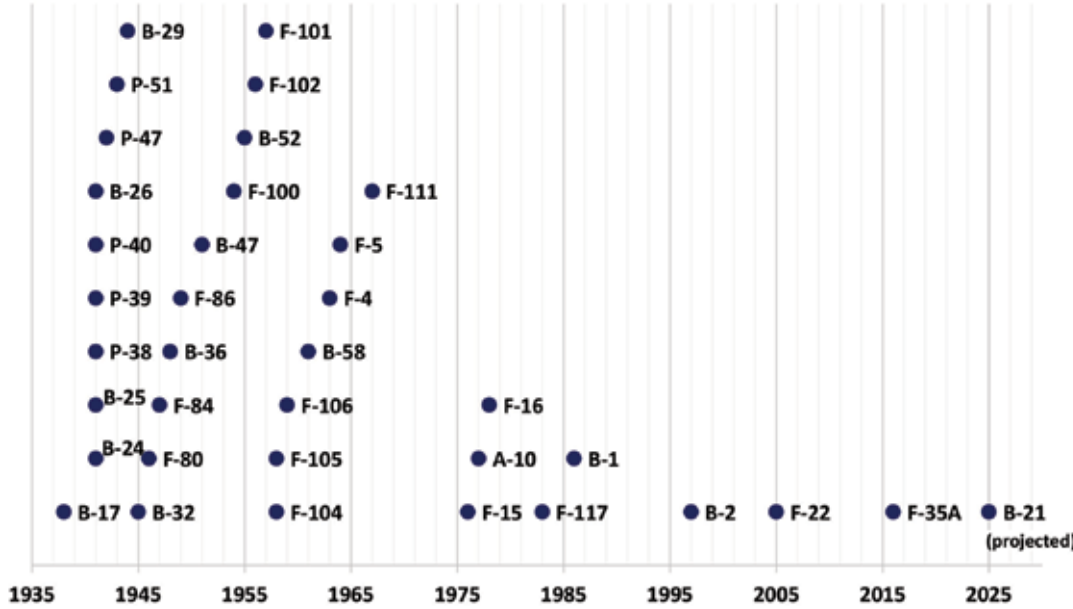
FIGURE 15: AIR FORCE COMBAT AIRCRAFT PROCUREMENT BY YEAR



Since the end of the Cold War, the Air Force has fielded roughly one new combat aircraft design per decade and, in the case of the B-2 and F-22, in numbers that were far short of the Air Force's original requirements. This is a significant break from the multiple new combat aircraft types fielded by administrations seeking to maintain the Air Force's technological edge over the Soviet Union during the Cold War (see Figure 16).[54]

54 Russia developed six generations of air defense systems during the nearly twenty-year period between the F-22 program's contract award and the F-22's initial operating capability date. Data for Figure 16 is primarily from Marcelle Size Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems Volume II: Post-World War II Fighters 1945–1973* (Washington, DC: Office of Air Force History, 1978); and Marcelle Size Knaack, *Encyclopedia of U.S. Air Force Aircraft and Missile Systems Volume II: Post-World War II Bombers 1945–1973* (Washington, DC: Office of Air Force History, 1988). Other sources were used for initial operational capability dates.

FIGURE 16: YEARS NEW COMBAT AIRCRAFT ACHIEVED OPERATIONAL STATUS



This procurement pattern has also had a deleterious impact on the U.S. defense industrial base's ability to sustain its high-end aircraft design workforce and production capabilities. As a result, there has been increasing specialization within the industrial base, such as the shifting of some design capabilities from prime manufacturers to first- and second-tier suppliers that focus on specific types of subsystems. This emphasis on modifying existing aircraft instead of designing new ones and the specialization within different tiers of the aerospace sector has helped to create an increasingly brittle industrial base.[55]

Summary

Although it is true that the Air Force is a far more lethal force today than it was in the early 1990s, increases in lethality must be assessed against future threat environments, not just the ability to support present-day contingency operations. The last true recapitalization and modernization of the Air Force's CAF, air refueling, manned ISR, and BMC2 aircraft inventories occurred in the late 1970s and 1980s. Air Force budget increases in the 2000s were mostly used to upgrade its existing inventory and recapitalize its airlift forces. As such, this is often referred to as a period of "hollow growth." Most Air Force aircraft procured during the Reagan administration defense build-up have been upgraded multiple times to maintain their operational utility and extend their service lives. Upgraded 4th generation combat aircraft can

55 For more on the status of the aircraft industrial base see DoD, *Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States* (Washington, DC: DoD, September 2018); and John Birkler, Paul Bracken, Gordon T. Lee, Mark A. Lorell, Soumen Saha, and Shane Tierney, *Keeping A Competitive U.S. Military Aircraft Industry Aloft: Findings from an Analysis of the Industrial Base* (Arlington, VA: RAND Corporation, 2011).

be more lethal and survivable than their predecessors, but cannot achieve a degree of survivability comparable to 5th generation aircraft designs. Additionally, much of the increased funding allocated to the Air Force during the hollow build-up of the 2000s was consumed by increased O&M and military personnel costs (see Table 13).[56]

TABLE 13: SUMMARY OF KEY FINANCIAL TRENDS FOR THE AIR FORCE (FY1962 - FY2019)

	Historical Average Normalized by Air Force TAI	Current Spending Normalized by Air Force TAI	Percent Increase 1990 to 2019
O&M	$6.38 million	$11.26 million	112%
MILPERS	$4.90 million	$6.20 million	25%
RDT&E	$2.37 million	$5.68 million	154%
Aircraft Modification Funding (Budget Program 11)	$0.44 million	$0.78 million	74%
Aircraft Procurement Funding (Budget Program 10)	$1.39 million	$1.90 million	22%

Air Force RDT&E funding has also increased above its historical average, but new technologies that are not yet on the ramp will not help maintain the Air Force's overmatch against great power competitors. To operate successfully in the contested and highly contested environments of the future, the Air Force will need resources to develop and *procure* next-generation aircraft.

56 Data was extracted from the ABIDES database, "Historical AF Blue TOA (Includes 19PB Approps, and OCO)," provided by the Air Force.

CHAPTER 2

Major Strategic Shifts that Should Inform Air Force Planning

Chapter 2 provides an assessment of major shifts in the security environment that should inform requirements for the Air Force's future aircraft inventory. The chapter begins with an overview of the challenges posed by China and Russia's military strategies, operating concepts, and capabilities that seek to undermine the U.S. military's traditional approaches to projecting power. The sections that follow summarize emerging threats to U.S. air forces, their regional airbases, and other infrastructure critical to future joint air operations. A final section summarizes how these threats should inform the Air Force's future force planning, including priorities for a force planning construct proposed in Chapter 3.

The Return of Great Power Competition

Competition between the United States and the revisionist governments of China and Russia has intensified over the last decade. Although China and Russia are each pursuing their own unique national aims, they both perceive the liberal international order as a threat to their authoritarian regimes and an obstacle to their long-term strategic goals. China and Russia seek to erode regional and international norms to reshape the global order in their favor, in part by undermining the influence of the United States and its allies in the Indo-Pacific region and in Europe respectively. This presents a major challenge to the security of the United States and the stability of the international system.[57]

57 Hal Brands and Eric S. Edelman, *Why is the World So Unsettled? The End of the Post-Cold War Era and the Crisis of Global Order* (Washington, DC: Center for Strategic and Budgetary Assessments, 2017), pp. 11–15.

In the Indo-Pacific region, China's leaders view America's post-Cold War dominance as a transitory condition. As part of the process to restore its power, wealth, and influence, China seeks to extend its control over disputed areas inside the Western Pacific's First Island Chain,[58] erode confidence in the United States as a regional security guarantor, and ultimately establish itself as the dominant regional power.[59] China's leaders have taken progressively bolder steps to achieve their objectives. These include declaring an air defense identification zone (ADIZ) in the East China Sea (ECS) as well as rejecting the United Nations Convention on the Law of the Sea tribunal ruling over disputed claims, building artificial islands, and militarizing disputed geographical features in the South China Sea (SCS). Simultaneously, Beijing is both courting and intimidating America's allies and partners in the region.[60] Underpinning these actions is a major military buildup dating back to the 1990s that has provided China with significant force overmatch relative to its neighbors and the means to offset some of the U.S. military's long-standing advantages. China's military modernization programs, combined with the actions it has taken to increase China's control over sensitive areas in the South and East China Seas, are intended to create doubt that the U.S. military will be able to project decisive power within the First Island Chain to defend America's regional allies and partners.

Although China's primary strategic focus has been on the Western Pacific, it also seeks to project power further afield. China has been procuring blue water multi-mission naval vessels and, likely foreshadowing future developments, has opened its first overseas military base in Djibouti.[61] In pursuit of its long-term aspirations to compete globally with the United States as a peer, China has used its growing technical and engineering know-how and economic resources to expand its influence and create a foundation for future power projection operations. China's Belt and Road Initiative, nominally a massive regional infrastructure plan intended to link and develop new markets for China across Eurasia and Africa, has significant implications for the security of the Indo-Pacific region.[62] To cite one example, Chinese investments in foreign ports and terminals have often been followed by port visits from Chinese naval vessels; it's important to note that Chinese state-owned enterprises operate at least

58 The First Island Chain in the Western Pacific follows the Japanese island of Kyushu down the Ryukyus to the north of Taiwan, runs west toward Luzon, then south along Palawan to Singapore. The Second Island Chain includes the northern Marianas and the Volcano Islands, runs south to Guam, then down to Palau and New Guinea.

59 Office of the Secretary of Defense (OSD), *Military and Security Developments Involving the People's Republic of China 2017*, Annual Report to Congress (Washington, DC: OSD, May 15, 2017), pp. i–ii; and DoD, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge* (Washington, DC: DoD, January 2018).

60 Thomas G. Mahnken, Ross Babbage, and Toshi Yoshihara, *Countering Comprehensive Coercion: Competitive Strategies Against Authoritarian Political Warfare* (Washington, DC: Center for Strategic and Budgetary Assessments, May 30, 2018).

61 DoD, *Assessment on U.S. Defense Implications of China's Expanding Global Access* (Washington, DC; DoD, December 2018), available at https://media.defense.gov/2019/Jan/14/2002079292/-1/-1/1/expanding-global-access-report-final.pdf.

62 Thomas S. Eder, "Mapping the Belt and Road Initiative: This Is Where We Stand," *MERICS Belt and Road Tracker*, June 7, 2018, available at https://www.merics.org/en/bri-tracker/mapping-the-belt-and-road-initiative.

76 ports and terminals in 34 different countries.[63] Such actions have prompted concerns of creeping Chinese influence in Central Asia, Africa, and Europe. In the case of India, Chinese projects have created concerns that China is encircling and encroaching on India's "zone of strategic interest."[64] Projecting itself as sharing similar development and modernization goals with the developing world, China is also exporting its technical expertise in artificial intelligence, facial recognition, and other areas to help countries such as Ecuador to develop domestic surveillance systems.[65] These efforts serve to advance China's narrative that its authoritarian system is an effective and efficient alternative to democracy.[66] Collectively, China's willingness to use its growing military and economic might to compete with the United States and its allies presents a complex challenge to the stability and security of the Indo-Pacific and other regions.[67]

In Europe, a resurgent Russia seeks to regain its great power status by attempting to dominate former Soviet and Warsaw Pact states, ultimately undermining the integrity and credibility of NATO. Russia's post-Cold War loss of control over these territories eliminated its traditional buffer zone and amplified its perceived vulnerabilities along its western flank.[68] Although Russia's desire to reestablish a security buffer against NATO is not new, the past decade has seen a marked increase in both the intensity of what Russia perceives as encroachment on its "privileged sphere of influence" and its willingness to use military, economic, information, and other elements of national power to achieve its objectives. Recent manifestations of this willingness include Russia's 2008 attack on Georgia, its 2014 annexation of Crimea, and its subsequent invasion of eastern Ukraine. In stark contrast to hopes that Russia would liberalize in the aftermath of the Cold War, Russian leaders now openly tout the virtues of their conservative authoritarian system and call for the creation of a "post-West world order."[69]

63 Elizabeth C. Economy, "China's New Revolution: The Reign of Xi Jinping," *Foreign Affairs*, May/June 2019, available at https://www.foreignaffairs.com/articles/china/2018-04-17/chinas-new-revolution.

64 Ryan Heath and Andrew Gray, "Beware Chinese Trojan Horses in the Balkans, EU Warns," *Politico*, July 27, 2018; and Nicholas Szechenyi, ed., *China's Maritime Silk Road: Strategic and Economic Implications for the Indo-Pacific Region* (Washington, DC: Center for Strategic and International Studies, March 2018), p. 30.

65 Charles Rollet, "Ecuador's All-Seeing Eye Is Made in China," *Foreign Policy*, August 9, 2018, available at https://foreignpolicy.com/2018/08/09/ecuadors-all-seeing-eye-is-made-in-china/.

66 Thomas Wright, "The Return to Great-Power Rivalry Was Inevitable," *The Atlantic*, September 12, 2018, available at https://www.theatlantic.com/international/archive/2018/09/liberal-international-order-free-world-trump-authoritarianism/569881/.

67 White House, *National Security Strategy of the United States of America* (Washington, DC: The White House, December 2017), p. 46.

68 Stephen Kotkin, "Russia's Perpetual Geopolitics," *Foreign Affairs* 95, no. 3, May/June 2016, p. 4.

69 Lizzie Dearden, "Russia's Foreign Minister Calls for 'Post-West World Order' in Speech to Global Leaders," *Independent*, February 18, 2017; and James Kirchick, "The Road to a Free Europe Goes Through Moscow," *Politico Magazine*, March 17, 2017.

Even as Russia continues to probe NATO's periphery for weaknesses, it seeks to expand its influence into other regions that it considers essential to its great power status.[70] Russia's military deployments to Syria since 2015 have demonstrated its ability to project power and have provided a testing ground for advanced military capabilities such as cruise missiles, unmanned systems, electronic warfare assets, and long-range air defense systems.[71] Russia has also dispatched two of its strategic bombers capable of carrying nuclear weapons to Venezuela, in part to demonstrate the renewed global reach of its armed forces.[72] Despite its struggling economy, Russia remains a world leader in the production and export of military equipment. Arms sales help Russia's defense-industrial base maintain production lines where domestic demand may be insufficient and deepen Russia's relationships with customer countries.[73] Exploiting its abundant energy resources and expansive system of pipeline networks, Russia leverages the energy dependence of other states, particularly in Europe, to extract political favors and exert influence.[74] Russia has also utilized increasingly sophisticated and intense political warfare campaigns and cyberattacks to affect political campaigns, candidates, and public discourse to undermine trust in the democratic process and institutions.[75]

In summary, although capabilities available to Russia are different and, in some respects, more limited than those utilized by China, both states are investing in the means to expand their influence further abroad and weaken competitor countries and alliances perceived to be aligned against their revisionist aims.

70 Eric Edelman and Whitney M. McNamara, *U.S. Strategy for Maintaining a Europe Whole and Free* (Washington, DC: Center for Strategic and Budgetary Assessments, February 16, 2017), p. 10.

71 Dave Majumdar, "Russia Boasts of Using 215 New Weapons Systems in Syria," *War is Boring*, February 1, 2018. A significant portion of funding for the Syria operation comes from Russia's planned training budget. See Anna Maria Dyner, "Three Months of Russian Intervention in Syria: The Military and Political Implications," *Bulletin*, Polish Institute of International Affairs, January 8, 2016, available at https://www.pism.pl/files/?id_plik=21212.

72 Michael Zennie, "Here's Why Russian Bombers Are in Venezuela. And Why the U.S. Is So Angry About It," *Time Magazine*, December 13, 2018, available at http://time.com/5478644/venezuela-russian-bombers/. This is part of Russia's broader effort to expand its presence in Latin America, using power projection to erode U.S. leadership and influence in the Western Hemisphere. See for example Julia Gurganus, "Russia: Playing a Geopolitical Game in Latin America," Carnegie Endowment for International Peace, May 2018, available at https://carnegieendowment.org/files/Gurganus_Russia_Latin_America_Geopolitcal_Game_May_2018_final.pdf.

73 Richard Connolly and Cecilie Sendstad, *Russia's Role as an Arms Exporter: The Strategic and Economic Importance of Arms Exports for Russia* (London: Chatham House, The Royal Institute of International Affairs, March 2017).

74 Fifteen EU member states are dependent on Russia for more than half of their gas supplies. Rem Korteweg, *Energy as a Tool of Foreign Policy of Authoritarian States, in Particular Russia* (Brussels: European Parliament, Policy Department, Directorate-General for External Policies, April 2018), available at http://www.europarl.europa.eu/RegData/etudes/STUD/2018/603868/EXPO_STU(2018)603868_EN.pdf.

75 Juan C. Zarate, "The Cyber Attacks on Democracy," *The Catalyst*, no. 8, Fall 2017, available at https://www.bushcenter.org/catalyst/democracy/zarate-cyber-attacks-on-democracy.html.

Challenges to the U.S. Military's Post-Cold War Concept for Conventional Warfare

As summarized in Chapter 1, deploying a large, decisive force nearly unhindered and then launching a massive combined arms counteroffensive to restore the status quo and punish a regional aggressor formed the basis for DoD planning for much of the post-Cold War period. Advances in precision strike capabilities, information technologies, and other advanced weapon systems that came to fruition in the early 1990s helped the U.S. military to rapidly defeat less capable forces in Iraq, Bosnia, Kosovo, and Afghanistan. Recognizing that the United States could employ a similar approach to counter their own efforts to expand their territory or influence, Russia and China have both developed new, "informationized" approaches to warfighting that include operations in the gray zone. These gray zone operations often entail using special operations and paramilitary forces, but they still carry implications for the size and shape of the future U.S. Air Force. The increased reliance on gray zone operations is tightly linked to China and Russia's conventional modernization efforts because the latter enables the former. Investments in higher-end A2/AD systems that limit the ability of U.S. forces to project power in contested areas facilitate gray zone operations because they make it more difficult for U.S. forces to counter these smaller-scale and sometimes sub-conventional activities. As a result, it is necessary to consider the kinds of capabilities U.S. forces may need to defend against A2/AD challenges and the possibility that China or Russia would take advantage of their localized zones of force overmatch to escalate a gray zone engagement to a major conflict.

China's Informationized Warfare and Russia's New Type Warfare

China and Russia have closely assessed how the United States and other developed countries conducted major military operations since the end of the Cold War. For China, the 1991 Gulf War demonstrated that the United States had successfully operationalized information technologies for the conduct of warfare and, more broadly, as a means to shape the perceptions of foreign governments and populations in ways that were advantageous to U.S. security interests.[76] Since the Gulf War, China has sought to develop its own doctrine and modern "informationized" capabilities for warfare. China accelerated its military modernization after the 1995–1996 Taiwan Strait Crisis that demonstrated the U.S. ability to intervene against China. China's inability to respond to the accidental bombing of its embassy in Belgrade during the 1999 Kosovo conflict further underscored gaps between the U.S. military and PLA capabilities, prompting Beijing to develop "assassin's mace [or trump card] weapons that can

76 Andrew Scobell, David Lai, and Roy Kamphausen, eds., *Chinese Lessons from Other Peoples' Wars* (Carlisle, PA: Strategic Studies Institute, November 2011), available at http://ssi.armywarcollege.edu/pdffiles/pub1090.pdf.

look far, shoot far, and shoot accurately" as part of its effort to develop an informationized military able to win local wars under informationized conditions.[77]

Today, the PLA has adopted what it calls Informationized Warfare as the core of its warfighting approach. PLA experts have described Informationized Warfare as "warfare where there is widespread use of informationized weapons and equipment and networked information systems, employing suitable tactics, in joint operations in the land, sea, air, outer space, and electromagnetic domains, as well as the cognitive arena."[78] In the PLA's view, achieving information dominance, or the ability to collect, manage, analyze, and exploit information better than the adversary, has become the priority mission in modern warfare.[79] Achieving information dominance requires targeting not just data and the systems involved in its collection and management, but also the people that analyze and use it. The human element is particularly important since Informationized Warfare encompasses capabilities to influence and control an opponent's psychology and will to fight.[80] This is evident in the PLA concept of "three warfares": public opinion warfare, psychological warfare, and legal warfare. These three approaches to warfare are employed in complementary ways to control the prevailing discourse and influence perceptions held by the Chinese domestic audience, an adversary's leadership and population, and relevant international third parties.[81] During conflict, Informationized Warfare targets the information resources, the information channels, and the processing and decision-making systems of an adversary to prevent its leadership from gaining an accurate picture of the battlespace. It also seeks to gain information dominance by using kinetic and non-kinetic capabilities as part of an integrated joint operation in all domains to target the weak points of an enemy's networks and paralyze or destroy its operational systems.[82] This involves the use of Chinese forces in "system-of-systems warfare" that pit China's networked combat, command and control (C2), reconnaissance and intelligence, and support systems against an enemy's system-of-systems.

77 June Teufel-Dreyer, *The PLA and the Kosovo Conflict* (Carlisle, PA: Strategic Studies Institute, May 2000); and Scott W. Harold, *Defeat, Not Merely Compete: China's View of Its Military Aerospace Goals and Requirements in Relation to the United States* (Santa Monica, CA: RAND Corporation, 2018).

78 Dean Cheng, Senior Research Fellow, Asian Studies Center, Davis Institute for National Security and Foreign Policy, "Information Dominance: The Importance of Information and Outer Space in Chinese Thinking," testimony to the House Foreign Affairs Committee, April 26, 2017, p. 3, available at http://docs.house.gov/meetings/FA/FA05/20170426/105885/HHRG-115-FA05-Wstate-ChengD-20170426.pdf.

79 Peng Guangqian and Yao Youzhi, *The Science of Military Strategy* (Beijing, China: Military Science Publishing House, 2005), pp. 338–339.

80 Cheng, "Information Dominance," p. 5.

81 For more on the PLA's three warfares, see Peter Mattis, "China's 'Three Warfares' in Perspective," *War on the Rocks*, January 30, 2018, available at https://warontherocks.com/2018/01/chinas-three-warfares-perspective/. The PLA is but one organization within China's party-state system that seeks to create a disposition of power so favorable to the PRC as to render the use of military force unnecessary to secure its interests.

82 Jeffrey Engstrom, *Systems Confrontation and System Destruction Warfare: How the Chinese People's Liberation Army Seeks to Wage Modern Warfare* (Santa Monica, CA: RAND Corporation, 2018).

Russia's evolving military strategy, referred to by Russian military theorists as "New Type Warfare,"[83] similarly seeks to integrate all instruments of national power to achieve Russia's strategic objectives. Central to this approach is information warfare, which incorporates Soviet-era subversion and destabilization techniques updated for the information age with lessons learned from observing U.S. military operations. Russia believes the 1991 Gulf War demonstrated not only the effectiveness of U.S. precision strike weapons, but also that future wars would entail "information confrontation . . . [since] information is becoming the very same kind of weapon as missiles, bombs, torpedoes and so on."[84] This emphasis on information warfare sprang from a realization that the center of gravity in modern conflict often isn't territory but an adversary's will to resist, which can be targeted more efficiently by intense disinformation campaigns in combination with electronic warfare to disable an adversary's command, control, and communications (C3) networks.[85] The Russian leadership's perceptions of the West's ability to use information operations to incite instability and remove regimes it disapproved of during the "color revolutions" in Georgia, Kyrgyzstan, and Ukraine reinforced their belief that controlling the information space is a relatively low-cost means to advance Russia's security interests.[86]

Russian military experts postulate that gaining information superiority will be key to winning future wars, although the appropriate combination of tools and methods will vary depending on the nature of a conflict.[87] Leveraging the hyper-connectivity of modern society that provides more direct access to its target audiences, Russia plans to employ information-psychological warfare to influence the perception and behavior of the adversary's civilian population, military forces, and the international community at all levels.[88] Russia uses the Internet, social media, trolls, bots, and the burgeoning number of professional and amateur journalists and media outlets as force multipliers to ensure Russian narratives reach target audiences.[89] Concurrently, Russia plans to conduct information-technology warfare to degrade, disrupt, and destroy the adversary's decision-making structures and C3 networks. New Type Warfare

83 For a discussion of New Type Warfare, see Timothy L. Thomas, "The Evolving Nature of Russia's Way of War," *Military Review* 97, no. 4, July/ August 2017.

84 В.И.Слипченко [V. I. Slipchenko], Война будущего *[Future War]* (Moscow: Moscow Public Science Foundation, 1999), as cited in English in Keir Giles, *Handbook of Russian Information Warfare* (Rome: NATO Defense College, 2016), p. 34, available at http://www.ndc.nato.int/news/news.php?icode=995.

85 András Rácz, *Russia's Hybrid War in Ukraine: Breaking the Enemy's Ability to Resist* (Helsinki, Finland: The Finnish Institute of International Affairs, June 2016), pp. 34–35.

86 Keir Giles, *Russia's "New" Tools for Confronting the West: Continuity and Innovation in Moscow's Exercise of Power* (London: Chatham House, The Royal Institute of International Affairs, March 2016), p. 10.

87 Квачков Владимир [Vladimir Kvachkov], Спецназ России *[Russia's Special Forces]* (online: Военная литература [Military Literature], 2004), available at http://militera.lib.ru/science/kvachkov_vv/index.html, as cited in English in Giles, *Handbook of Russian Information Warfare*, p. 3.

88 For a summary of current Russian strategic thought, see Dmitry (Dina) Adamsky, *Cross-Domain Coercion: The Current Russian Art of Strategy* (Paris: French Institute of International Relations Security Studies Center, November 2015), pp. 23–24.

89 Christopher Paul and Miriam Matthews, *The Russian "Firehose of Falsehood" Propaganda Model* (Santa Monica, CA: RAND Corporation, 2016).

combines kinetic attacks such as severing an enemy's communication channels and seizing communications infrastructure with non-kinetic actions including cyberattacks to disrupt communications and power grids.[90] These actions aim to incapacitate "a state as much as possible before that state is even aware that a conflict has started,"[91] minimizing the need to employ military force. Whatever military action proves necessary is accompanied by the continuation of massive deception and disinformation campaigns, maximizing the operational and tactical freedom of maneuver of Russian forces.

Whereas industrial-age warfare of the past sought to defeat an enemy by destroying its means to fight, shaping the information domain during peacetime and achieving information dominance in war are the main line of effort for both China and Russia's new warfighting strategies. Their key objective is to reduce the necessity to use hard military power by convincing an adversary's leadership not to fight, demoralizing its military and civilian population, and undermining trust in their government. If military force must be applied, it is done so in a coordinated joint operation to degrade an adversary's ability to process and act on information to render its operations ineffective.[92]

Gray Zone Aggression

Both Chinese and Russian conventional modernization efforts are closely linked with their militaries' increasing reliance on gray zone warfare to achieve strategic objectives. Their investments in higher-end A2/AD systems that threaten U.S. power projection facilitate their gray zone and information operations and make it more difficult for U.S. forces to disrupt sub-conventional activities with light military footprints. China and Russia have increasingly resorted to gray zone operations, an element of Informationized Warfare, to pursue objectives along their periphery while avoiding direct confrontation with the United States and its allies. Gray zone operations entail the use of diplomatic, information, military, economic, and other instruments of national power in integrated campaigns to achieve objectives such as gaining control over territory or a regional population without having to escalate to a major conflict.[93] Gray zone operations are designed to remain below the level of violence likely to provoke a full-scale U.S. or allied response, often relying on special forces, proxies, and paramilitary groups in combination with non-kinetic effects.

90 Giles, *Russia's "New" Tools for Confronting the West*.

91 A. J. C. Selhorst, "Russia's Perception Warfare," *Military Spectator* 185, no. 4, 2016, p. 151, as cited in Giles, *Handbook of Russian Information Warfare*, p. 6.

92 It is important to note that this is more than just a theoretical warfighting approach: it has already been successfully employed. In just over three weeks, Russia forced all 193 Ukrainian bases in Crimea to surrender without firing a shot, breaking what little resistance they encountered by using low levels of violence. U.S. Army Special Operations Command, *"Little Green Men": A Primer on Modern Russian Unconventional Warfare, Ukraine 2013–2014* (Fort Bragg, NC: U.S. Special Operations Command, June 2015), p. 57.

93 Joseph L. Votel, Charles T. Cleveland, Charles T. Connett, and Will Irwin, "Unconventional Warfare in the Gray Zone," *Joint Forces Quarterly* 80, 1st quarter, 2016. Also see Hal Brands, "Paradoxes of the Gray Zone," *E-Notes*, Foreign Research Policy Institute, February 5, 2016, available at https://www.fpri.org/article/2016/02/paradoxes-gray-zone/.

China has used its coast guard and paramilitary naval forces to expand its influence in the South and East China Seas. China has already achieved a *fait accompli* in the South China Sea by occupying disputed islands, building artificial ones on existing features, and militarizing a number of them by deploying assets such as bombers, missiles, and jammers.[94]

Russia's gray zone aggression in Crimea and eastern Ukraine are part of its long-term campaign to discredit NATO and regain influence over former Soviet and Warsaw Pact states. Russia has used its military, paramilitary, and irregular forces combined with information and political warfare in Georgia, Moldova, and Ukraine to prevent these countries from strengthening ties with Western institutions.[95] More recently, Russia ratcheted up its efforts to destabilize Montenegro to preclude its planned accession into the European Union, generally reversing its Western trajectory.[96] The relative success of these actions may encourage further gray zone aggression by China or Russia in the future.[97]

Although utilizing a lighter military footprint, Chinese and Russian gray zone operations along their periphery are backed by their localized force overmatch, raising the potential costs of a U.S. or coalition attempt to intervene on behalf of a country under attack.[98] Gray zone and information warfare operations are a threat precisely because they are backstopped by the more advanced conventional A2/AD capabilities in which both countries have heavily invested. Should a gray zone conflict escalate, China or Russia are prepared to leverage their time-distance advantage and localized military overmatch to act rapidly and present the United States and its allies with a *fait accompli* before they could effectively respond.[99] The planning scenarios summarized in Chapter 3 and used by CSBA to assess the Air Force's future aircraft inventory requirements assumed that gray zone aggression by China and Russia in the South China Sea and the Baltic Sea region, respectively, were a prelude to major conventional conflicts with the United States and its allies.

94 For more on China's attempts to exert de facto control in its near-seas region, see Ronald O'Rourke, *China's Actions in South and East China Seas: Implications for U.S. Interests—Background and Issues for Congress* (Washington, DC: Congressional Research Service, 2018).

95 Robert Orttung and Christopher Walker, "Putin's Frozen Conflicts," *Foreign Policy*, February 13, 2015, available at https://foreignpolicy.com/2015/02/13/putins-frozen-conflicts/.

96 Reuf Bajrović, Vesko Garčević, and Richard Kraemer, *Hanging by a Thread: Russia's Strategy of Destabilization in Montenegro* (Philadelphia: Foreign Policy Research Institute, June 2018).

97 Olga Oliker, Senior Adviser and Director, Russia and Eurasia Program, Center for Strategic and International Studies, "Russian Influence and Unconventional Warfare Operations in the 'Grey Zone': Lessons from Ukraine," Statement before the Senate Armed Services Committee, Subcommittee on Emerging Threats and Capabilities, March 29, 2017, available at https://www.armed-services.senate.gov/imo/media/doc/Oliker_03-29-17.pdf.

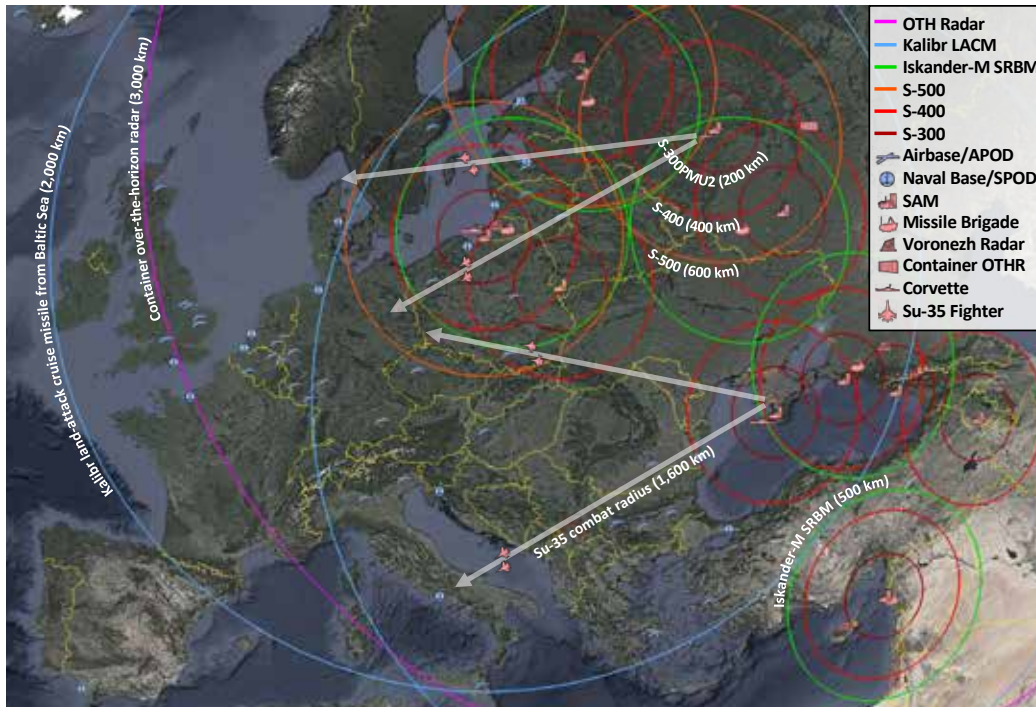
98 For more on regaining escalation dominance and winning in the gray zone, see Bryan Clark, Mark Gunzinger, and Jesse Sloman, *Winning in the Gray Zone: Using Electromagnetic Warfare to Regain Escalation Dominance* (Washington, DC: Center for Strategic and Budgetary Assessments, October 2017).

99 China and Russia can mass forces close to a conflict zone located adjacent to their borders. This provides them with a geographic advantage, and thus a time-distance advantage, over the U.S. military forces that must respond from their garrisons in the continental United States.

China and Russia's Military Priorities Support their Strategies

China and Russia have developed A2/AD complexes to support their military strategies.[100] China's A2/AD complex includes overlapping active and passive air and missile defenses, early warning and target-tracking sensors, low-observable cruise missiles, sophisticated conventional ballistic missiles, increasingly advanced combat aircraft, growing fleets of UAVs, and, in the near-future, hypersonic weapons.[101] China's area-denial umbrellas cover strategic locations in the East and South China Seas and enable the PLA to hold targets at risk in Japan, Vietnam, Taiwan, the Philippines, and the homelands of other regional rivals. China is augmenting the density and reach of its A2/AD complex by equipping small islands in the East and South China Seas with air defense systems, cruise missiles, electronic warfare systems, sensors, and runways for military aircraft. Russia's A2/AD systems located in Kaliningrad, its Western Military District, and in Belarus, its near-client state, form a protective umbrella over much of the Baltic Sea region. A similar network based in Russia's Southern Military District envelopes the Black Sea region.

FIGURE 17: RUSSIAN A2/AD COVERAGE OVER THE BALTICS AND BLACK SEA REGIONS



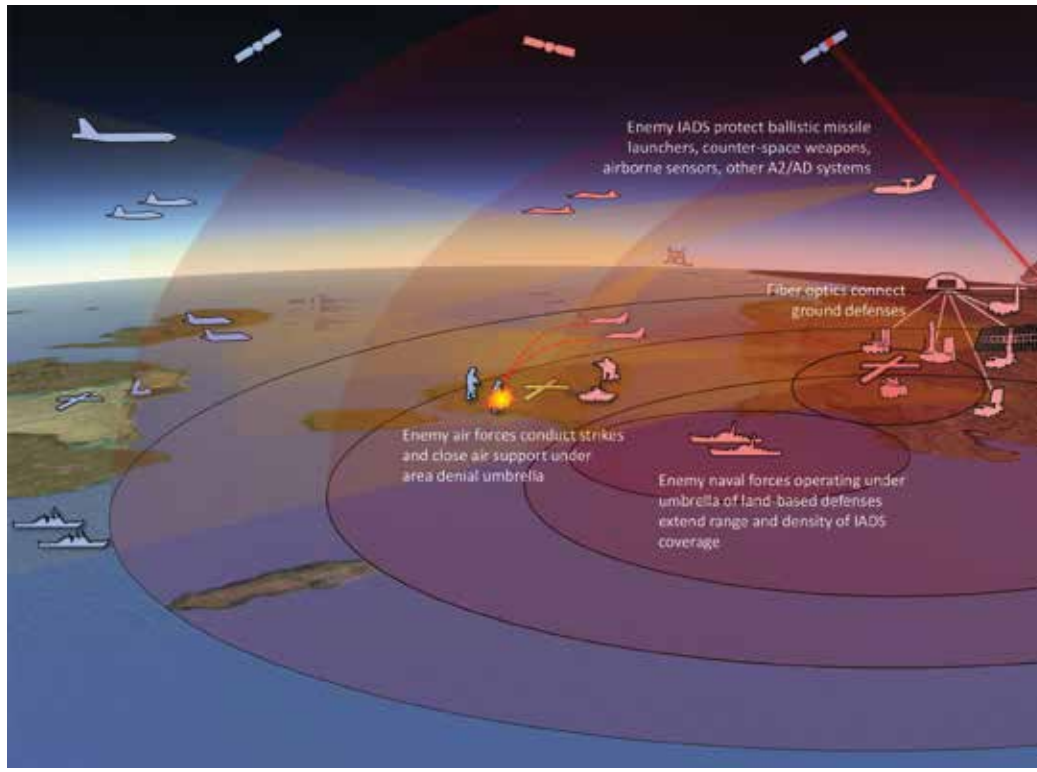
Data to build this graphic derived IHS Jane's (2019).

100 Barry D. Watts, *The Maturing Revolution in Military Affairs* (Washington, DC: Center for Strategic and Budgetary Assessments, 2011).

101 Defense Intelligence Agency (DIA), *China Military Power: Modernizing a Force to Fight and Win* (Washington, DC: DIA, 2019), available at http://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/China_Military_Power_FINAL_5MB_20190103.pdf.

China's and Russia's A2/AD capabilities also provide cover for their gray zone actions (see Figure 18).[102]

FIGURE 18: CHINESE AND RUSSIAN IADS PROVIDE COVER FOR THEIR MILITARY OPERATIONS IN MULTIPLE DOMAINS



Should the United States move to defend its allies and partners from gray zone aggression, China and Russia could employ their long-range reconnaissance-strike capabilities to target ports, airfields, and other bases that the United States and its allies have traditionally relied on to marshal forces. They could also use their IADS to deny access and freedom of maneuver to U.S. air forces, creating windows in time and space to achieve and solidify their gains. China and Russia could complement these operations by conducting non-kinetic (e.g., cyber) attacks and possibly kinetic strikes against their adversaries' homelands. These efforts would be part of a larger Informationized Warfare campaign that is intended to convince the United States and its allies that a military response would be too costly and, in the end, fail to prevent China or Russia from achieving its campaign objectives.

Over most of the past 25 years, the U.S. military assumed it would have near-unimpeded access to regional bases, possess or could rapidly achieve air superiority, and operate in

102 Clark, Gunzinger, and Sloman, *Winning in the Gray Zone*, pp. 17–18.

littoral waters almost unopposed. It also assumed that regional conflicts would proceed slowly enough for large formations of U.S. forces to arrive in a theater and then quickly compel a return to the *status quo ante bellum*. Furthermore, U.S. military planners assumed that if a lesser power were able to achieve its objectives initially, the United States could mass sufficient forces to conduct a successful counteroffensive.

This crisis response CONOPS is now an inadequate template for the U.S. military's future force planning for two main reasons: the emergence of A2/AD weapon systems that can threaten U.S. forces at long range, and the ability of China and Russia to use their time, distance, and local correlation of forces advantages to rapidly achieve their objectives before the United States and its allies can respond.[103] To reverse this trend, the U.S. military will need to change its planning assumptions and resource priorities toward creating a future Joint Force that is more survivable, lethal, and able to quickly suppress Chinese and Russian A2/AD threats. The next section provides a more in-depth assessment of Chinese and Russian threats to future U.S. air operations.

Threats to Future Air Force Operations

The United States has had significant military advantages over the opponents it has fought since the end of the Cold War in the Balkans, the Middle East, and Central Asia. This has been particularly true in the air domain, where the United States has had the ability to quickly achieve air supremacy. The perceived lack of a peer adversary and the need to allocate resources toward counterinsurgency and counter-terror operations were significant factors in DoD decisions to forgo investments in advanced air capabilities needed for future high-end operations. This created a window of opportunity for Russia and China to develop advanced ballistic and cruise missiles, IADS, anti-satellite (ASAT) weapons, cyber capabilities, and other capabilities that are eroding America's airpower advantage. This section summarizes Russian and Chinese threats to the U.S. Air Force's theater airbases, its forces, and supporting networks and infrastructure that will be essential to its future conduct of multi-domain operations.

Threats to U.S. Theater Airbases and Other Fixed Installations

The Air Force depends on access to overseas bases to conduct multi-domain operations as part of a joint force. Since the Cold War, it has been able to operate from large theater bases that were considered to be virtual sanctuaries from attacks. The lack of a threat to DoD's overseas bases contributed to its shift toward creating an overseas posture that includes large, centralized, and highly efficient main operating bases that lack sufficient active and passive defenses

103 See, for example, David A. Shlapak and Michael Johnson, "Outnumbered, Outranged, and Outgunned: How Russia Defeats NATO," *War on the Rocks*, April 21, 2016; and Eric Heginbotham et al., *The U.S.-China Military Scorecard: Forces, Geography, and the Evolving Balance of Power, 1996–2017* (Santa Monica, CA: RAND Corporation, 2015).

against air and missile attacks.[104] Given the crucial role of air operations to the success of modern operations, competitors have sought to develop capabilities to negate the U.S. military's airpower advantages by targeting its air forces where they are most vulnerable—on the ground.[105] Today, China and Russia's precision strike capabilities, particularly their ballistic and cruise missiles, pose significant challenges to theater airbases, C2 nodes, satellite ground stations, staging areas, and other facilities critical to U.S. military operations. In a future conflict with China or Russia, the range and density of their strike systems will likely make it very challenging for the Air Force to conduct large-scale operations from airbases that are located within range of these threats.[106] Large salvos of precision weapons could result in significant attrition to U.S. air forces on the ground and severe damage to fuel tanks, munitions storage areas, and other critical enablers that would significantly reduce the Air Force's ability to generate sorties.

China's strike complex. China's PLA Rocket Force (PLARF) fields the world's largest and most capable inventory of theater ballistic missiles. These missiles are solid-fueled and road mobile, making them difficult to interdict prior to launch. China's ballistic missile arsenal includes approximately 1,200 short-range ballistic missiles (SRBM) that are mostly postured to attack targets in Taiwan. The PLARF also has approximately 200 to 300 medium-range ballistic missiles (MRBM) such as the DF-21 and a new DF-16 that can reach targets along the First Island Chain in the Pacific. A number of Chinese intermediate-range ballistic missiles (IRBM), including the DF-26 and its expected variants, can reach targets located along the Second Island Chain.[107] China has made significant investments to improve its ballistic missile warhead payloads, their accuracy, and ability to counter U.S. missile defenses such as the Patriot-3 and Standard Missile-3 interceptors.[108]

104 Alan J. Vick, *Air Base Attacks and Defensive Counters: Historical Lessons and Future Challenges* (Santa Monica, CA: RAND Corporation, 2015), p. 52; and Mark Gunzinger and Carl Rehberg, *Air and Missile Defense at a Crossroads: New Concepts and Technologies to Defend America's Overseas Bases* (Washington, DC: Center for Strategic and Budgetary Assessments, October 2018).

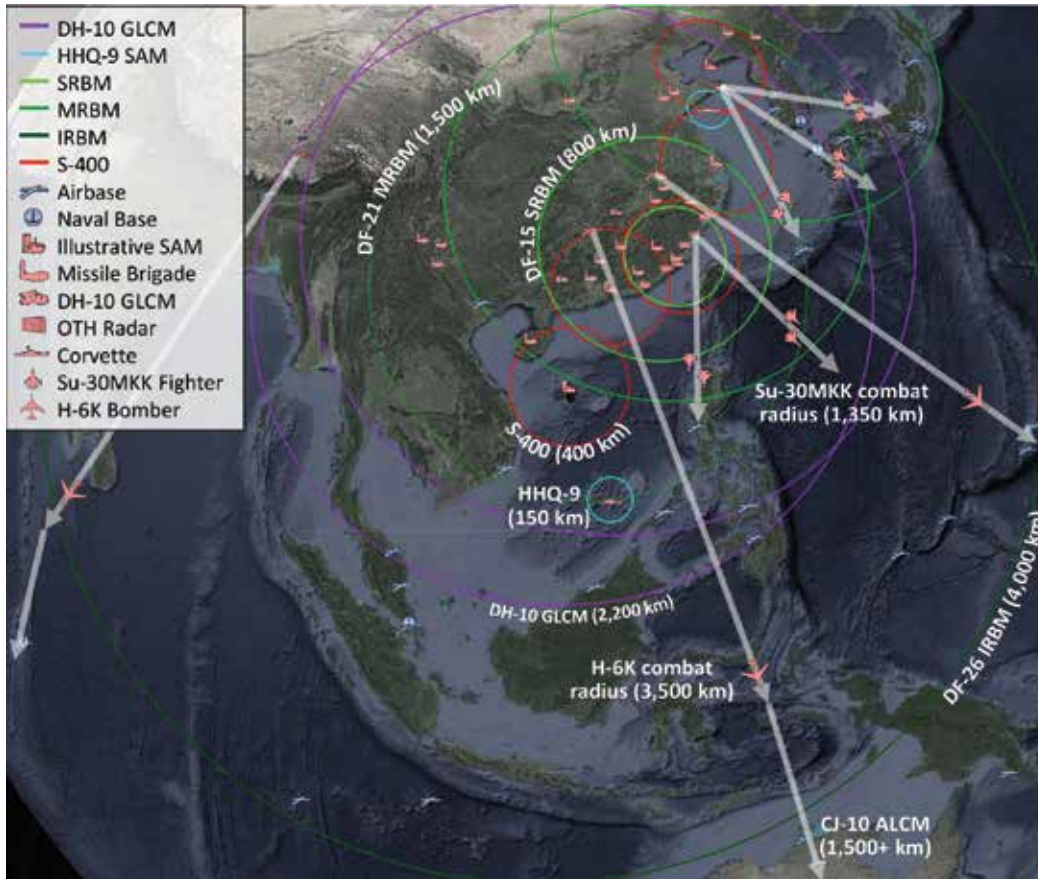
105 U.S. Air Force, Enterprise Capability Collaboration Team, *Air Superiority 2030 Flight Plan* (Washington, DC: U.S. Air Force, May 2016), available at https://www.af.mil/Portals/1/documents/airpower/Air%20Superiority%202030%20Flight%20Plan.pdf.

106 Vick, *Air Base Attacks and Defensive Counters*.

107 OSD, *Military and Security Developments Involving the People's Republic of China 2018*, pp. 59–63, 70–71.

108 Ian Easton, *China's Evolving Reconnaissance-Strike Capabilities: Implications for the U.S.-Japan Alliance* (Arlington, VA and Tokyo: Project 2049 and The Japan Institute of International Affairs, February 2014).

FIGURE 19: CHINA'S STRIKE COMPLEX EXTENDS BEYOND THE FIRST ISLAND CHAIN



Data to build this graphic derived from IHS Jane's (2019); and OSD, *Military and Security Developments Involving the People's Republic of China 2018*.

Following decades of sustained investments in cruise missile technologies, China now has thousands of advanced cruise missiles that it can fire from multiple platforms.[109] The PLA has developed the CJ-10 ground-launched cruise missile (GLCM); an air-launched version of the CJ-10 called the CJ-20 that has a range of approximately 1,500 km; and numerous other ALCM variants.[110] In recent years, the PLA Air Force (PLAAF) has significantly expanded its training operations for overwater bombing operations, flying H-6K bombers past the First Island Chain into the Western Pacific Ocean to within cruise missile range of Guam. PLAAF bombers have been escorted by AWACS and fighter aircraft to provide defensive counterair protection.[111] China is also developing new medium- and long-range stealth bombers.[112] One of these platforms, the H-20, is anticipated to have an unrefueled range of 12,000 km and

109 Gunzinger and Rehberg, *Air and Missile Defense at a Crossroads*, pp. 4-5.

110 Easton, *China's Evolving Reconnaissance-Strike Capabilities*.

111 OSD, *Military and Security Developments Involving the People's Republic of China 2018,* p. 118.

112 DIA, *China Military Power*, p. 85.

a munitions payload of roughly 40,000 lbs.[113] China's ability to strike regional bases will be further augmented by attack submarines and surface combatants capable of launching land attack cruise missiles (LACM).[114] Analysis of prior and ongoing PLA activities suggests that cruise missiles may be one of a series of assassin's mace capabilities that China has sought to develop for years that could potentially play a significant role in determining the outcome of future conflicts.[115]

Attacks on U.S. airbases and other fixed theater installations would likely entail the coordinated use of multiple types of munitions to saturate and overwhelm their defenses.[116] China could launch an initial wave of ballistic missiles to neutralize base air defenses, suppress base C2 centers, and crater runways to trap U.S. aircraft on the ground. This initial salvo could be followed by waves of cruise missiles and airstrikes against aircraft shelters, aircraft parked in the open, and fuel handling and maintenance facilities.[117] Images obtained from commercial satellites show that China has constructed mock targets representing Kadena Air Base in Okinawa and possibly other bases and port facilities in the Western Pacific. The PLARF uses these mock targets to conduct practice attacks, which is consistent with the PLA's *Science of Military Strategy* that lists the primary mission of the PLARF as "suppressing enemy air force air bases, airfields, and missile defense (air defense) systems."[118]

Russia's strike complex. Russia has fielded multiple cruise missile variants that can be launched from its submarines, ships, aircraft, and mobile land batteries. In 2015 and 2017, Russian submarines launched a number of 3M14 Kalibr LACMs against targets located in Syria.[119] LACMs such as the 3M14 "provide even modest [naval] platforms with significant offensive capability . . . to hold distant fixed ground targets at risk using conventional warheads."[120] In 2017, Russia used its stealth Kh-101 ALCM to destroy ammunition depots

113 "China to Unveil Newest Long-Range Strategic Bomber During Military Parade in 2019," *Defence Blog*, October 15, 2018, available at https://defence-blog.com/news/china-to-unveil-newest-long-range-strategic-bomber-during-military-parade-in-2019.html.

114 Oriana Skylar Mastro and Ian Easton, *Risk and Resiliency: China's Emerging Air Base Strike Threat* (Arlington, VA: Project 2049, November 2017).

115 Liu Tonglin, Ni Yonghua, and Liu Yin, eds., *Cruise Missiles—The "Assassin's Mace" in High-Tech Warfare* (Beijing: Military Arts Press, 2002), pp. 1–9. The term assassin's mace is best translated in colloquial English as "silver bullet." Also see Carl Rehberg, review of Dennis M. Gormley, Andrew S. Erickson, and Jingdong Yuan, "A Low Visibility Force Multiplier: Assessing China's Cruise Missile Ambitions," *Strategic Studies Quarterly*, Summer 2014, pp. 148–151.

116 Roger Cliff et al., *Shaking the Heavens and Splitting the Earth: Chinese Air Force Employment Concepts in the 21st Century* (Santa Monica, CA: RAND Corporation, Project Air Force, 2011), p. 48; and David Hambling, "After Cluster Bombs: Raining Nails," *Wired.com,* May 30, 2009, available at https://www.wired.com/2008/05/after-cluster-b/.

117 Thomas Shugart and Javier Gonzalez, *First Strike: China's Missile Threat to U.S. Bases in Asia* (Washington, DC: Center for a New American Security, June 2017).

118 Skylar Mastro and Easton, *Risk and Resiliency*, p. 3. Also see Shugart and Gonzalez, *First Strike*, pp. 4–6.

119 "Game Changer: Russian Sub-launched Cruise Missiles Bring Strategic Effect," *Jane's International Defence Review,* April 27, 2017.

120 Office of Naval Intelligence (ONI), *The Russian Navy: A Historic Transition* (Washington, DC: ONI, December 2015), p. 34.

and a command post in Syria.[121] The backbone of Russia's future theater strike aircraft inventory will be its modernized bombers, the Tu-160M2 Blackjack, the Tu-22M3 Backfire, and potentially the PAK-DA stealth bomber. Each of these aircraft can carry large payloads of air-to-surface missiles.

Russia has a large number of 4th generation multi-role fighters that are each capable of carrying multiple long-range cruise missiles externally in addition to various loadouts of shorter-range air-to-surface weapons. Moscow has also developed a land-based 9M729 GLCM that violates the effectively defunct 1987 Intermediate-Range Nuclear Forces (INF) Treaty.[122] According to media reports, Russia has deployed one or more battalions of these missiles integrated with mobile Iskander-K launch vehicles.[123] Once launched, cruise missiles are difficult to detect and track, particularly by ground-based radars, due to their maneuverability, low-altitude flight paths, and, for some variants, stealth features. This presents a significant challenge to the Air Force's ability to defend its airbases and other military installations. Whereas the U.S. military has invested heavily in ballistic missile defenses, it has a limited capacity to counter large salvos of cruise missiles and other non-ballistic guided weapons.[124] Air-, ground-, and sea-launched Kh-101, 9M728, and 3M14 LACMs, each with a range of at least 2,000 km, pose a significant threat to NATO airbases and other military installations located throughout Europe, including the United Kingdom (see Figure 20).

Russia's arsenal of conventional ballistic missiles includes multiple SRBM variants such as the 9K720 Iskander-M weapon system. These are mounted on road-mobile transporter erector launchers (TEL) that remain in concealed positions throughout mission preparation. TELs require only a brief exposure to fire their missiles, and can relocate within minutes to other concealed locations, making them difficult to find, fix, track, and interdict. By 2020, Russian armed forces are expected to field ten Iskander-M brigades with the combined capacity to launch about 480 missiles, assuming each launcher has a single missile reload.[125]

In March 2018, the Russian Air Force announced that it had taken delivery of new Kh-47M2 Kinzhal hypersonic air-launched ballistic missiles, which can be carried by modified MIG-31BM supersonic aircraft. With a claimed range of 2,000 km, the Kinzhal would be able strike virtually every NATO airbase in Europe without their launch aircraft leaving Russian

121 Polina Nikolskaya and Dmitry Solovyov, "Russia Hits Islamic State in Syria with Advanced Cruise Missiles," *Reuters World News*, July 5, 2017, available at https://www.reuters.com/article/us-mideast-crisis-syria-russia-idUSKBN19Q1QP.

122 General Paul Selva testified at a HASC hearing in March 2017 that the U.S. believes Russia has "deployed a land-based cruise missile that violates the spirit and intent" of the 1987 INF Treaty and it poses a threat to NATO. John M. Donnelly, "Hill Wants Answers on Russia's Fielding of New Missiles," *Roll Call,* March 8, 2017, available at https://www.rollcall.com/news/hill-wants-answers-russias-fielding-new-missiles.

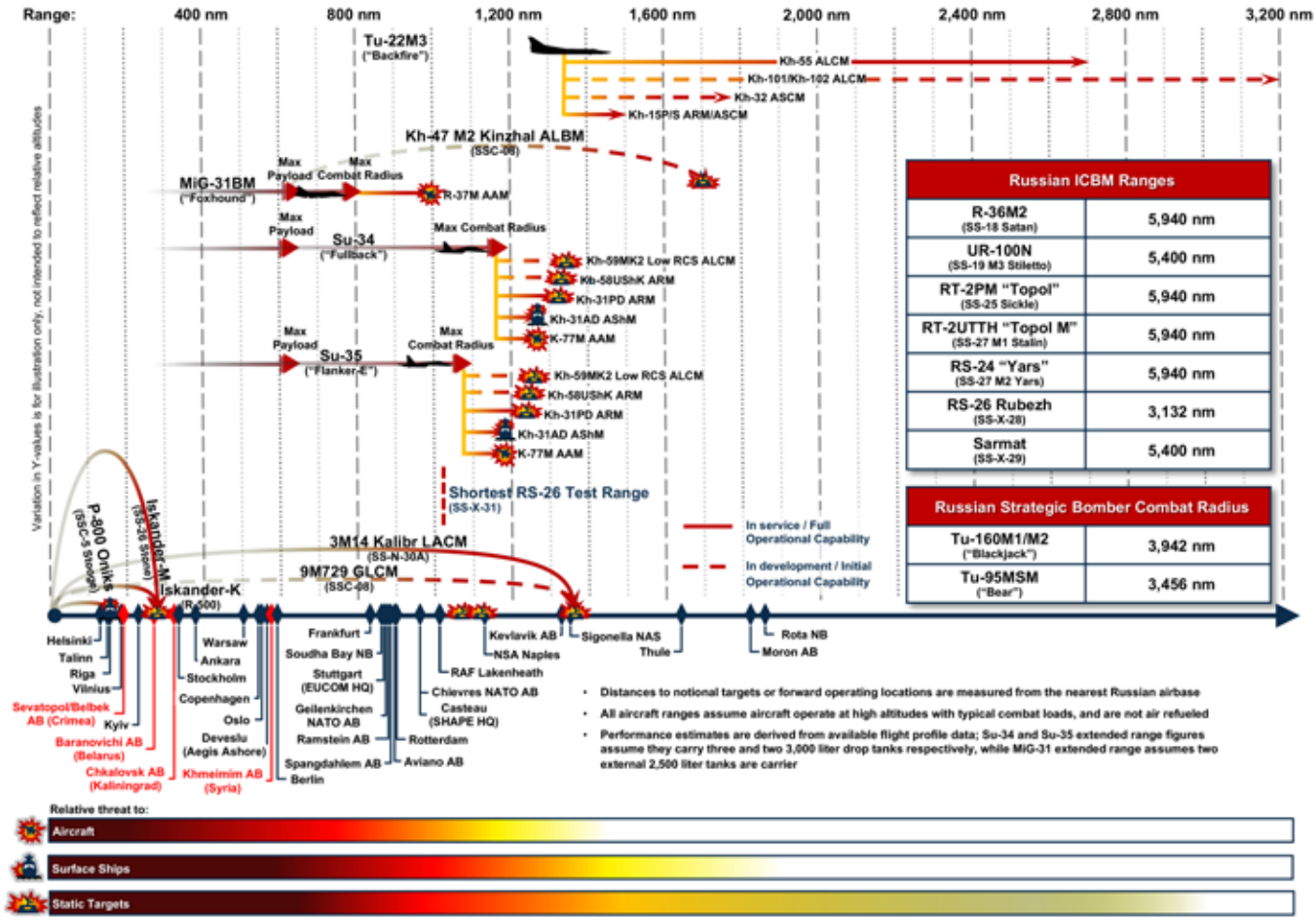
123 Michael R. Gordon, "Russia Deploys Missile, Violating Treaty and Challenging Trump," *New York Times,* February 14, 2017, available at https://www.nytimes.com/2017/02/14/world/europe/russia-cruise-missile-arms-control-treaty.html?mcubz=3.

124 Gunzinger and Rehberg, *Air and Missile Defense at a Crossroads*.

125 Ibid., p. 6.

airspace. Russian crews from a MIG-31 squadron have already flown 250 training sorties in support of this mission.[126] It is envisioned that the Kinzhal will be deployed with hypersonic boost-glide vehicles (HGV) that maneuver after separation from their boosters and fly depressed trajectories that make them difficult to intercept.[127]

FIGURE 20: RUSSIA CAN STRIKE TARGETS ACROSS EUROPE



Data to build this graphic was derived from IHS Jane's (2019); National Air and Space Intelligence Center (NASIC), *Ballistic and Cruise Missile Threat* (2017); and CSIS Missile Threat (2019).

126 Neil Gibson and Nikolai Noichkov, "Russian Aerospace Forces Take Delivery of 'New' Kinzhal Air-launched Ballistic Missile," *Jane's Missiles and Rockets,* March 19, 2018. See also "Kinzhal," *Missile Threat,* Missile Defense Project, Center for Strategic and International Studies, March 27, 2018, updated June 15, 2018, available at https://missilethreat.csis.org/missile/kinzhal/.

127 Gunzinger and Rehberg, *Air and Missile Defense at a Crossroads*, p. 6.

Threats to U.S. Airborne Systems

China and Russia's A2/AD complexes include IADS that are designed to impose costs on U.S. air forces and deny their freedom of maneuver in the battlespace. According to DoD, IADS are more than networks of surface-to-air missile launchers:

> An enemy IADS attempts to destroy, disrupt, or neutralize intelligence collection and air and missile attacks or other penetrations of their airspace. To degrade the effectiveness of OCA operations, enemy defensive tactics may include jamming aircraft navigation, communications, target acquisition systems, and precision weapons guidance systems.[128]

In addition to directly attacking U.S. aircraft, Chinese and Russian IADS can impose a form of virtual attrition on U.S. air forces by causing them to operate less effectively or efficiently. To cite one case, non-stealth strike aircraft must increase their standoff ranges from targets that are defended by long-range and highly lethal strategic SAMs such as Russia's S-400 and China's HQ-9. These standoff ranges would require aircraft to launch long-range weapons that are typically larger and more expensive than short-range, direct attack munitions. The need to use payloads of standoff weapons could greatly increase the number of U.S. sorties and the cost to successfully attack a major target set. Non-stealth BMC2 aircraft such as the E-3 AWACS and E-8 JSTARS would also have to increase their standoff from long-range enemy defenses, which would reduce their ability to provide an accurate picture of the battlespace without the support of penetrating ISR capabilities. Even stealth systems that penetrate contested and highly contested airspace must plan their ingress and egress routes to avoid high-risk areas, and they may require the use of supporting aircraft and weapons to suppress some defenses. Both approaches would have the effect of increasing resources needed to conduct strikes, provide close air support to friendly forces, and perform other air missions. Moreover, it may take a major level of effort and a significant amount of time to degrade Chinese and Russian air defenses that can quickly relocate and take advantage of large numbers of decoys, camouflage, and other resiliency measures. This level of effort could slow the pace of all U.S. joint operations in contested and highly contested environments.[129]

China's IADS. The PLA accelerated its efforts to field state-of-the-art air defense systems by importing weapon systems and technologies from Russia. China has fielded operational battalions of the Russian-sourced S-300PMU1/2 SAM and the domestically produced HQ-9 that China likely developed using Russian S-300P and U.S. Patriot interceptor technology.[130] Variants of the HQ-9 have modern HT-233 target engagement radars that could, according

128 Joint Chiefs of Staff (JCS), *Countering Air and Missile Threats*, Joint Publication 3-01 (Washington, DC: JCS, April 21, 2017), p. xvii.

129 Unlike the United States, Russia has shaped its ground forces to operate without air superiority. Russia's substantial investments in organic air defense and electronic warfare systems illustrate the point. Sean O'Connor, Konrad Muzyka, and Huw Williams, "Analysing Russia's SAM Capabilities: Deployments, Capabilities, and Future Prospects," *Jane's* by IHS Markit briefing, August 31, 2017.

130 Sean O'Connor and Huw Williams, "Chinese Strategic SAM Systems: Deployments, Capabilities, and Future Prospects," *Jane's* by IHS Markit briefing, November 30, 2017.

to some sources, engage six targets simultaneously (two missiles per target) out to 200 km.[131] China is also acquiring six battalions of Russian manufactured S-400 SAMs.[132] If paired with the 40N6 missile, which Russia will likely export, S-400 systems will be able to engage aircraft out to 400 km. China could use S-400s to create an air defense barrier along its entire east coast that could also range all of Taiwan and the Senkakus.[133] China also continues to invest heavily in stealth technologies and sensors to detect stealth aircraft. These efforts have led to China's development and deployment of digital very high frequency (VHF) band radars such as the JY-26.[134]

Many of China's advanced air defense systems are highly mobile and have electronic countermeasures that improve their survivability. Electronic countermeasures such as frequency hopping enable Chinese sensors to counter various types of jamming and better discriminate between decoys and actual targets.[135] The mobility of IADS radars and launch vehicles make them difficult to locate, especially if Chinese forces avoid activating their search radars or take other actions that could increase their probability of detection.

Networking is another increasingly important feature of China's IADS. China has tested an HQ-9 battle management radar similar to Russia's 64N6 radar series that would allow them to control individual groupings of HQ-9 batteries.[136] Once a target is detected by an early warning sensor network, regimental or division command posts can assign target track data to the individual battalions that can achieve the best firing solution. The mobility of newer IADS sensor and weapons systems provides an additional layer of flexibility and resiliency. China has also deployed medium-range HQ-16 and short-range HQ-7 SAM systems to fill gaps in the IADS network and provide additional defensive capacity in critical areas.[137]

As formidable as China's ground-based interceptors are, they do not provide full area coverage of its airspace. The majority of China's strategic SAM systems are deployed along its eastern coastline to counter threats that may try to attack from the east. China is deploying airborne early warning and control (AEW&C) aircraft such as the KJ-2000 and KJ-500 to extend the range of its IADS beyond China's coastline. These aircraft incorporate modern radars that provide faster target acquisition time, more accurate target position data, and an improved

131 O'Connor and Williams, "Chinese Strategic SAM Systems."

132 OSD, *Military and Security Developments Involving the People's Republic of China 2017*, p. 29; and U.S.-China Economic and Security Review Commission (USCC), *2017 Report to Congress* (Washington, DC: U.S. Government Publishing Office, November 2017), p. 210.

133 O'Connor and Williams, "Chinese Strategic SAM Systems."

134 Wendell Minnick, "China's Anti-Stealth Radar Comes to Fruition," *Defense News*, November 22, 2014, available at https://www.defensenews.com/global/asia-pacific/2014/11/22/chinas-anti-stealth-radar-comes-to-fruition/.

135 O'Connor and Williams, "Chinese Strategic SAM Systems."

136 Sean O'Connor, "Imagery Shows New HQ-9 Radar at Chinese SAM Training Site," *Jane's Defence Weekly*, October 4, 2013.

137 O'Connor and Williams, "Chinese Strategic SAM Systems."

ability to detect low-altitude and low-observable targets.[138] The PLAAF is planning to field 5th generation fighters that have advanced avionics, advanced radar tracking and targeting capabilities, and integrated electronic warfare systems.[139] Leveraging advances in sensor capabilities and connectivity among platforms, the PLAAF will be able to use its AEW&C or J-20s to cue J-16 fighters to engage enemy aircraft with very-long-range advanced air-to-air missiles.[140] China envisions utilizing this concept to defend against U.S. strike and combat support aircraft. These long-range capabilities are augmented by air defenses on the PLA Navy's surface ships, providing PLAAF AEW&C, J-20s, and J-16s the freedom to maneuver and attack without being harassed by U.S. airpower. Unlike older PLA Navy (PLAN) ships that were equipped with point defenses, new ships entering the force are equipped with medium- or long-range SAMs such as the HHQ-9.[141]

To defend critical assets within its interior, China has co-located early warning radars with airbases that host air-to-air interceptors. These radars can provide ground-controlled interception data to fighters, expanding the depth of coverage of China's IADS. These defenses are backed by early warning radar complexes spread throughout China that provide near-total coverage across the country.

Russia's IADS. Russia remains a leader in developing state-of-the-art radar, surface-to-air missiles, electronic warfare systems, and other air defense capabilities.[142] Russia's IADS modernization programs have focused on improving the ranges and target seeker technology of its surface-to-air missiles and enhancing its ability operate in EMS environments. Once integrated with new 40N6 surface-to-air missiles, Russia's S-400 strategic SAM system will have an engagement range of up to 400 km against aerodynamic targets and up to 15 km against ballistic weapons.[143] A single S-400 battery may be able to engage ten targets simultaneously with two missiles per target.[144] Russia has tested its more advanced S-500 system, which can reportedly engage non-stealth aircraft at ranges out to 600 km as well as 5th

138 DIA, *China Military Power*, p. 85.

139 OSD, *Military and Security Developments Involving the People's Republic of China 2018*.

140 Jeffrey Lin and P.W. Singer, "China Is Testing a New Long-range, Air-to-Air Missile that Could Thwart U.S. Plans for Air Warfare," *Eastern Arsenal*, Popular Science blog, November 22, 2016, available at https://www.popsci.com/china-new-long-range-air-to-air-missile.

141 Ronald O'Rourke, *China Naval Modernization: Implications for U.S. Navy Capabilities—Background and Issues for Congress* (Washington, DC: Congressional Research Service, August 2018.)

142 DIA, *Russia Military Power: Building a Military to Support Great Power Aspirations* (Washington, DC: DIA, 2017), p. 62, available at http://www.dia.mil/Portals/27/Documents/News/Military%20Power%20Publications/Russia%20Military%20Power%20Report%202017.pdf. The Russian Aerospace Forces (VKS) is the primary command responsible for bringing together Russia's aviation systems, air and missile defense systems, early warning assets, and space control and monitoring systems under a unified and integrated command and control structure. Russian Ground Forces also operate significant numbers of mobile, ground-based air defense systems to provide maneuver forces with an organic air and missile defense capability, further complicating U.S. and allied efforts to achieve air superiority over contested areas.

143 Oscar Widlund, "The SAM Factory: Russian Air-Defence Capabilities," *Jane's Defence Weekly*, October 24, 2018.

144 O'Connor, Muzyka, and Williams, "Analysing Russia's SAM Capabilities."

generation stealth aircraft and cruise and ballistic missiles over shorter ranges.[145] These systems employ sophisticated missiles with multi-mode seekers, dynamic flight controls for maneuverability, and improved capability to engage multiple targets.

Below the strategic tier, Russian Ground Forces operate medium-range air defenses such as the 9K40 Buk-M2 and the newer Buk-M3, while the Russian Aerospace Forces (VKS) plans to deploy the S-350 Vitjaz to replace older versions of the S-300. These medium-range defenses augment Russia's more limited inventories of long-range interceptors, help increase radar coverage within air defense zones, and fill gaps in coverage. Russian Ground Forces also operate the Tunguska-M short-range anti-aircraft gun and missile system and variants of the 9K331 Tor system to defend mobile military formations. The VKS operates higher-capacity, shorter-range air defenses such as the Pantsir-S2 to defend strategic SAMs and other high-value military assets.[146] Russia plans to further augment its air defenses with the short-range 42S6 Morfey system and, possibly, high-power directed energy weapons within the next decade.[147] At the tactical level, Russia fields numerous man-portable air-defense systems (MANPADS) such as the 9K333 Verba and the 9k36 Strela.

Russia's air defense doctrine prioritizes creating overlapping, multi-layered coverage zones. Russian ground-based interceptors employ a hierarchical structure in which a single battle manager controls numerous batteries that are each assigned to defend a different sector.[148] Each battle management complex uses its organic radar systems combined with external inputs from Russia's early warning network to generate target track data that it sends to an assigned battery following threat prioritization. This approach improves target deconfliction and allows Russian fire control systems to calculate the best firing solution for each identified target.[149] The mobility of Russia's air defenses allows them to be rapidly repositioned to create an optimum network. This reduces the ability of U.S. forces to isolate and attack the weakest links in Russian IADS and create safe air corridors for other U.S. penetrating aircraft and weapons.

Multi-layered IADS give Russian forces the ability to simultaneously engage a large number of air and missile threats. The Pantsir-S2 short- to medium-range air defense system that typically deploys with Russia's strategic SAMs increases the capacity of the overall system-of-systems to engage anti-radiation missiles, precision-guided munitions (PGM), UAVs, and other threats. They also free strategic SAMs to engage high-value air targets. Russian air

145 Amanda Macias, "Russia Quietly Conducted the World's Longest Surface-to-Air Missile Test," *CNBC*, May 24, 2018, available at https://www.cnbc.com/2018/05/24/russia-quietly-conducted-the-worlds-longest-surface-to-air-missile-test.html?__source=twitter%7Cmain; and "S-500 Prometheus," *Missile Threat*, Missile Defense Project, Center for Strategic and International Studies, May 4, 2017, updated June 15, 2018, available at https://missilethreat.csis.org/defsys/s-500-prometheus/.

146 DIA, *Russia Military Power*.

147 Widlund, "The SAM Factory."

148 O'Connor, Muzyka, and Williams, "Analysing Russia's SAM Capabilities."

149 Ibid.

defense units use camouflage, concealment, and deception (CCD) to limit their signature and can relocate within minutes to reduce the probability that they will be located and attacked successfully. Smaller Russian air defense capabilities have their own sensors to detect and cue threat engagements independent of centralized, integrated C2 networks. Collectively, these systems create resilient IADS that would require a significant level of effort and amount of time to degrade.

Russia's IADS are supported by a multi-domain, multi-phenomenology network of sensors that can be connected using landline communications, making it very difficult to degrade their operations. The combination of long-range active and passive sensors with robust, jam-resistant communications give Russian air defense units an advantage against U.S air forces. Of note is the new Nebo-M system. The Nebo-M uses three different radar units integrated with a command post to detect and track low-observable targets. Although these systems rely on VHF-band radar systems that have been around for a long time, the introduction of digital signal processing and active electronically scanned array (AESA) radars have improved Russia's ability to detect and track targets.[150]

Although Russia's SAMs represent the most formidable future threat to U.S. air forces, they are augmented by hundreds of 4th generation aircraft such as the Flanker fighter series and MiG-31s. Even though these fighters are significantly less capable than U.S. fighters, they remain a threat to other U.S. non-stealth aircraft and will attack U.S. forces on the ground while operating under SAM umbrellas that deny U.S. aircraft access to the operational environment. In addition to Russia's limited success in reducing the radar cross sections of their most advanced fighters and their lack of on-board sensor fusion capabilities, their air-to-air missile (AAM) flight times and kinematic performance fall well short of legacy U.S. AAMs such as the AIM-120C series.[151] Recognizing these limitations, Russian counterair doctrine entails firing salvos of missiles with a mix of semi-active and/or active seekers, anti-radiation missiles, and heat seekers to complicate U.S. countermeasures.[152] Russia also continues to pursue concepts and capabilities such as the 400-km-range K-100 AAM designed for Flanker series fighters and the 230-km-range R-37 designed for the MiG-31 to conduct long-range air engagements against U.S. and NATO high-value aircraft.[153]

150 Ibid.

151 Tom Cooper, "Russia's Most Feared Air-to-Air Missile Is Actually Kind of a Dud," *War is Boring*, November 14, 2016, available at https://warisboring.com/russias-most-feared-air-to-air-missile-is-actually-kind-of-a-dud/.

152 Carlo Kopp, "The Russian Philosophy of Beyond Visual Range Air Combat," *Air Power Australia*, March 25, 2008, updated April 2012, available at http://www.ausairpower.net/APA-Rus-BVR-AAM.html.

153 Kyle Mizokami, "The Navy Wants to Give Its Bigger Planes a Way to Shoot Down Missiles," *Popular Mechanics*, May 9, 2018, available at https://www.popularmechanics.com/military/aviation/a20634418/navy-interceptor-for-larger-planes/.

Threats to U.S. Information Dominance

Information is the lifeblood of modern warfare. As the 2012 *Defense Strategic Guidance* noted, "Modern armed forces cannot conduct high-tempo, effective operations without reliable information and communication networks and assured access to cyberspace and space."[154] Although the U.S. military's reliance on timely information of the battlespace is not new, advances in sensors and networking technologies over the last forty years have fundamentally changed how the United States conducts military operations. In the later years of the Cold War, U.S. forces conducted and coordinated operations via voice communications and low-bandwidth datalinks. Today, information technologies underpin capabilities used by the U.S. military to build and exploit a high-fidelity operational picture of the battlespace.[155] Effectiveness in the battlespace increasingly hinges on the ability of a modern military to collect, manage, analyze, and exploit information faster and more accurately than an adversary. If a military can gain advantage in the information competition, it may be able to get inside an adversary's decision-making cycle and ultimately achieve decision dominance. The capability to act faster and more accurately than an enemy depends on communication networks; sensors that measure electromagnetic (EM) energy; the effective fusing and interpretation of information from sensors in all domains; and positioning, navigation, and timing (PNT) information from satellite navigation systems.

All these capabilities, at least to some degree, rely on the EMS, which has become increasingly congested and contested over the past two decades.[156] Having observed the military advantages the United States derived from its dominance of the EMS, China and Russia have developed systems and concepts that exploit vulnerabilities in America's sensor and communication networks with the intent of "dis-integrating" U.S. battle networks while preserving their own ability to operate effectively in the EMS.[157] Absent information assurance, the effectiveness of U.S. platforms, munitions, and C2 would substantially decline, which could

154 DoD, *Sustaining U.S. Global Leadership: Priorities for 21st Century Defense* (Washington, DC: DoD, January 2012), p. 5, available at http://archive.defense.gov/news/defense_strategic_guidance.pdf.

155 The second offset strategy used precision sensing and strike networks to enable U.S. and allied forces to defeat Soviet aggression despite the Union of Soviet Socialist Republic's (USSR) numerical advantages in troops, conventional military capabilities, and nuclear weapons. For more information, see Robert Martinage, *Toward a New Offset Strategy: Exploiting U.S. Long-Term Advantages to Restore U.S. Global Power Projection Capability* (Washington, DC: Center for Strategic and Budgetary Assessments, 2014), pp. 5–20.

156 Aside from the proliferation of commercial devices, U.S. combat forces themselves emit an enormous amount of electromagnetic energy, which can potentially interfere with friendly operations. For example, U.S. forces in Iraq and Afghanistan often inadvertently jammed each other while trying to disable roadside IEDs due to their lack of spectrum awareness. The advent of multi-function EM systems will exacerbate these effects, as almost every military system or person in the battlespace becomes an EM emitter or receiver.

157 For example, both Chinese and Russian electronic warfare units routinely conduct jamming and anti-jamming operations against multiple communication and radar systems and GPS satellite systems in force-on-force exercises, improving the ability of their forces to operate in a contested EM environment. For more on competition in the EMS and the potential for the United States to regain dominance, see Bryan Clark and Mark Gunzinger, *Winning the Airwaves: Regaining America's Dominance in the Electromagnetic Spectrum* (Washington, DC: Center for Strategic and Budgetary Assessments, 2017).

drastically increase the required number of sorties, potentially increase attrition, and increase the required inventory of aircraft and munitions.

EMS threats. The United States has leveraged EM technologies such as wideband transmitters and receivers and software-defined radios to field sophisticated C4ISR capabilities. The proliferation of these EM technologies has also enabled China and Russia to develop countermeasures to defeat U.S. C4ISR systems and disrupt the U.S. military's operations at every step of its find, fix, track, target, engage, and assess kill chains. These countermeasures include jammers to interfere with radars and radios, decoys that produce false targets for passive EM sensors, laser dazzlers to blind electro-optical/infrared (EO/IR) sensors, and camouflage that obscures potential targets. These capabilities span the strategic to the tactical level. For example, Russia's Murmansk-BN system has a reported range of 5,000 km and is designed to monitor, disrupt, and jam systems operating in the high frequency (HF) band such as the Air Force's High Frequency Global Communications System.[158] At the tactical level, Russian ground forces incorporate organic electronic warfare (EW) capabilities such as the R-330Zh Zhitel designed for detection, direction-finding, and downlink jamming of satellite communications within a local area. Among other effects, satellite downlink jamming can interfere with the GPS guidance systems of UAVs and PGMs.[159] The U.S. military's vulnerabilities in the EMS is compounded by the increasing range of Chinese and Russian A2/AD networks that may compel U.S. non-stealth aircraft to operate from greater stand-off ranges, requiring them to use higher-power active sensors and countermeasures that would further increase their detectability.[160]

Threats to U.S. space systems.[161] U.S. military operations are heavily reliant on satellite communications, the Global Positioning System (GPS) constellation that provides precision PNT information, ISR satellites, and other space-based systems. China and Russia have fielded capabilities to contest the space domain and exploit perceived vulnerabilities in U.S. space architecture.[162] DoD space systems are locatable, often reside in unprotected commer-

158 This network supports communications between U.S. C2 nodes and U.S. and NATO aircraft and vessels. For more information, see Jonas Kjellen, *Russian Electronic Warfare: The Role of Electronic Warfare in the Russian Armed Forces* (Stockholm, Sweden: Swedish Defence Research Agency, September 2018).

159 Roger N. McDermott, *Russia's Electronic Warfare Capabilities to 2025* (Tallinn, Estonia: International Centre for Defence and Security, September 2017), available at https://icds.ee/wp-content/uploads/2018/ICDS_Report_Russias_Electronic_Warfare_to_2025.pdf; and Brian Weeden and Victoria Samson, eds., *Global Counterspace Capabilities: An Open Source Assessment* (Broomfield, CO and Washington, DC: Secure World Foundation, April 2018), available at https://swfound.org/media/206118/swf_global_counterspace_april2018.pdf.

160 Clark and Gunzinger, *Winning the Airwaves*.

161 Defense Intelligence Agency (DIA), *Challenges to Security in Space* (Washington, DC: DIA, 2019) pp. 13–28, available at https://media.defense.gov/2019/Feb/11/2002088710/-1/-1/1/SPACE-SECURITY-CHALLENGES.PDF.

162 This includes vulnerabilities in orbital systems; terrestrial command, control, and space awareness facilities and networks; and other elements of the U.S. military and civilian space architectures. DoD and Office of the Director of National Intelligence (ODNI), *National Security Space Strategy: Unclassified Summary* (Washington, DC: DoD and ODNI, January 2011), available at http://archive.defense.gov/home/features/2011/0111_nsss/docs/NationalSecuritySpaceStrategyUnclassifiedSummary_Jan2011.pdf.

cial and military satellites, and are concentrated in a limited number of platforms, many of which could not be quickly replaced if damaged or compromised.[163] Both the PLA and Russian military are less dependent on space, in part because they have viable alternatives to support operations in areas located close to their homelands.[164] Consequently, China and Russia may be willing to use kinetic and non-kinetic ASAT weapons against U.S. space assets during a conflict that could also impact their own space systems.

Russia's military has benefitted from Soviet-era programs that developed operational ASAT weapons during the Cold War.[165] Its most recent kinetic ASAT tests have used direct-ascent technologies, although direct ascent systems currently in development may not be able to threaten targets in orbits higher than low Earth orbit (LEO).[166] This is partly due to the fact that some of these developmental ASATs are based on PL-19 Nudol and S-500 anti-ballistic missile systems. The PL-19 is capable of engaging targets in LEO, and the S-500 is primarily an exo-atmospheric ballistic missile defense system that could potentially reach targets in LEO.[167] Russia is also developing airborne kinetic and non-kinetic ASAT weapons that would provide it with a quick reaction capability for targets that are not within the range of the Nudol. In 2017, a Russian Aerospace Forces squadron commander confirmed that Russia is planning to deploy an air-launched ASAT on its MiG-31BM fighter, which is thought to be based on Russia's air-launched 78M6 Kontakt missile.[168] Russia's developmental Beriev A-60 airborne laser demonstrator could be capable of damaging or destroying space systems in LEO.[169] Russia also has a robust network of ground-based lasers ostensibly developed for scientific purposes that could be adapted for counterspace operations.[170] Since 2010, Russia has been testing technologies for space rendezvous and proximity operations (RPO) that could be utilized as co-orbital ASAT weapons.[171] Co-orbital ASAT weapons would provide Russia the capability to target U.S. satellites that are orbiting at altitudes higher than LEO.

China has developed multiple kinetic and non-kinetic ASAT weapon systems. Since its successful ASAT weapon test in 2007, China has continued to develop direct-ascent ASAT

163 John Grady, "U.S. Dependence on Space Assets Could be a Liability in a Conflict with China," *USNI News*, January 29, 2014, available at https://news.usni.org/2014/01/29/u-s-dependence-space-assets-liability-conflict-china.

164 Todd Harrison, Zack Cooper, Kaitlyn Johnson, and Thomas G. Roberts, *Escalation & Deterrence in the Second Space Age* (Washington, DC: Center for Strategic and International Studies, October, 2017).

165 DIA, *Challenges to Security in Space*, p. 29.

166 Todd Harrison, Kaitlyn Johnson, and Thomas G. Roberts, *Space Threat Assessment 2018* (Washington, DC: Center for Strategic and International Studies, April 12, 2018).

167 Weeden and Samson, *Global Counterspace Capabilities*.

168 Alexander Zudin, "Russia to Deploy Anti-satellite Weapon on MiG-31BM," *Jane's Missiles & Rockets*, February 22, 2017.

169 The airborne laser is a heavily modified variant of Russia's IL-76 transport aircraft. Sean O'Connor, "Russia's ASAT Development Takes Aim at LEO Assets," *Jane's Intelligence Review*, 2018.

170 Weeden and Samson, *Global Counterspace Capabilities*.

171 Ibid.

weapons such as the SC-19, which may be based on the DF-21C ballistic missile.[172] It is likely that China tested a direct-ascent ASAT in 2013 that could reach satellites in geosynchronous orbits, which would include U.S. satellites used for military communications, ISR, and missile launch detection.[173] China has developed and tested complex space rendezvous and proximity operations capabilities that could be employed as co-orbital ASAT weapons; as intelligence gathering platforms aimed at U.S. space systems; or as a means to jam, degrade, or otherwise disable U.S. or allied satellites. In July 2013, China successfully launched a satellite with a robotic arm that captured another of its satellites in space, and in June 2016, China launched an Aolong-1 satellite that is equipped with a robotic manipulator, allegedly for de-orbiting space debris.[174] Although these capabilities have legitimate applications for China's civilian manned space program, the technology is likely dual-use. China has also made significant advances in non-kinetic ASAT weapons, including ground-based lasers that can damage or disable space systems, as well as capabilities to jam common satellite communication bands and GPS signals.[175]

Cyber threats. Cyber tools provide additional means to disrupt and corrupt the U.S. ability to use information by targeting digital data and the information networks that store, process, and disseminate that data.[176] The adaptation and integration of information communication technologies present U.S. forces with a fundamental dilemma. Although these technologies significantly enhance the capabilities of U.S. forces, "the potential cybersecurity attack surface also increases," creating vulnerabilities that China or Russia could seek to exploit.[177] DoD's Defense Science Board has warned that "major powers (e.g., Russia and China) have a significant and growing ability to hold U.S. critical infrastructure at risk via cyberattack and an increasing potential to use cyber tools to thwart U.S. military responses."[178] Both China and Russia seem to be preparing for such operations by conducting cyber reconnaissance to collect

172 Ibid.

173 Harrison, Johnson, and Roberts, *Space Threat Assessment 2018*, p. 8.

174 USCC, *2015 Report to Congress* (Washington, DC: U.S. Government Publishing Office, November 2015), p. 295; and USCC, *2017 Report to Congress*, p. 214.

175 Daniel R. Coats, Director of National Intelligence, "Worldwide Threat Assessment of the US Intelligence Community," Statement for the Record, February 13, 2018, available at https://www.dni.gov/files/documents/Newsroom/Testimonies/2018-ATA---Unclassified-SSCI.pdf; and Harrison, Johnson, and Roberts, *Space Threat Assessment 2018*, p. 10.

176 Don Snyder et al., *Cybersecurity of Air Force Weapons Systems: Ensuring Cyber Mission Assurance Throughout a System's Life Cycle* (Santa Monica, CA: RAND Corporation, 2015).

177 Director, Operational Test and Evaluation (DOT&E), *FY2017 Annual Report* (Washington, DC: DOT&E. January 2018), p. i. available at http://www.dote.osd.mil/pub/reports/fy2017/pdf/other/2017DOTEAnnualReport.pdf; and Jacquelyn Schneider, *Digitally Enabled Warfare: The Capability Vulnerability Paradox* (Washington, DC: Center for a New American Security, August 2016).

178 Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics (OUSD/AT&L), *Defense Science Board Task Force on Cyber Deterrence*, final report (Washington, DC: OUSD/AT&L, February 2017), available at https://www.acq.osd.mil/dsb/reports/2010s/DSB-CyberDeterrenceReport_02-28-17_Final.pdf.

technical and operational data for broader intelligence operations and to support operational planning for potential cyberattacks.[179]

In the event of conflict, Chinese or Russian cyberattacks could delay, disrupt, degrade, and, where possible, negate some U.S. military capabilities. Both could attack military C2 networks to deny U.S. warfighters access to critical information, glean intelligence on U.S. operational planning and decision-making, or otherwise corrupt information to degrade the U.S. ability to make decisions. Logistics networks and critical civilian infrastructure on which U.S. military and civil activities depend would also be likely targets, particularly because they operate on unclassified networks that are easier to penetrate.[180] Additionally, cyberattacks could directly target U.S. weapons systems via their software, hardware, or firmware.[181] To cite one example, China or Russia could corrupt software to disable systems, induce false targets, make small changes to GPS signals, and interrupt command and control of U.S. drones.[182] They could also attempt to compromise the integrity of the U.S. microelectronics supply chain to, for example, sabotage components used in U.S. GPS-guided munitions. Beyond the immediate operational impacts of such attacks, China and Russia could attempt to undermine the U.S. military's confidence in its battlespace awareness systems, C2 network security, and the ability of its weapons systems to function properly.[183]

Threats to the U.S. Homeland

Air Force planners must consider operating concepts and capabilities it may need to counter threats to the U.S. homeland during future great power conflict. China's and Russia's new warfighting strategies include using cyberattacks and other non-kinetic means against C4ISR hubs, military logistics networks, and personnel management systems located in the United States to disrupt DoD's ability to deploy and sustain forces. They could also use similar means to target civilian power grids, telecommunications networks, and other civilian infrastructure with the goal of disrupting the U.S. economy and creating other effects to support their strategic objectives. Although a significant escalation, kinetic strikes against the United States must not be ruled out. In future great power conflicts, Chinese or Russian long-range air-launched or sub-launched cruise missiles could threaten the east and west coasts of the

179 Michael Sulmeyer, "Military Set for Cyber Attacks on Foreign Infrastructure," Harvard Kennedy School, Belfer Center for Science and International Affairs, April 11, 2018, available at https://www.belfercenter.org/publication/military-set-cyber-attacks-foreign-infrastructure.

180 Don Snyder et al., *Ensuring U.S. Air Force Operations During Cyber Attacks Against Combat Support Systems: Guidance for Where to Focus Mitigation Efforts* (Santa Monica, CA: RAND Corporation, 2015).

181 Jennifer McArdle, *Victory Over and Across Domains: Training for Tomorrow's Battlefields* (Washington, DC: Center for Strategic and Budgetary Assessments, 2019), p. 7.

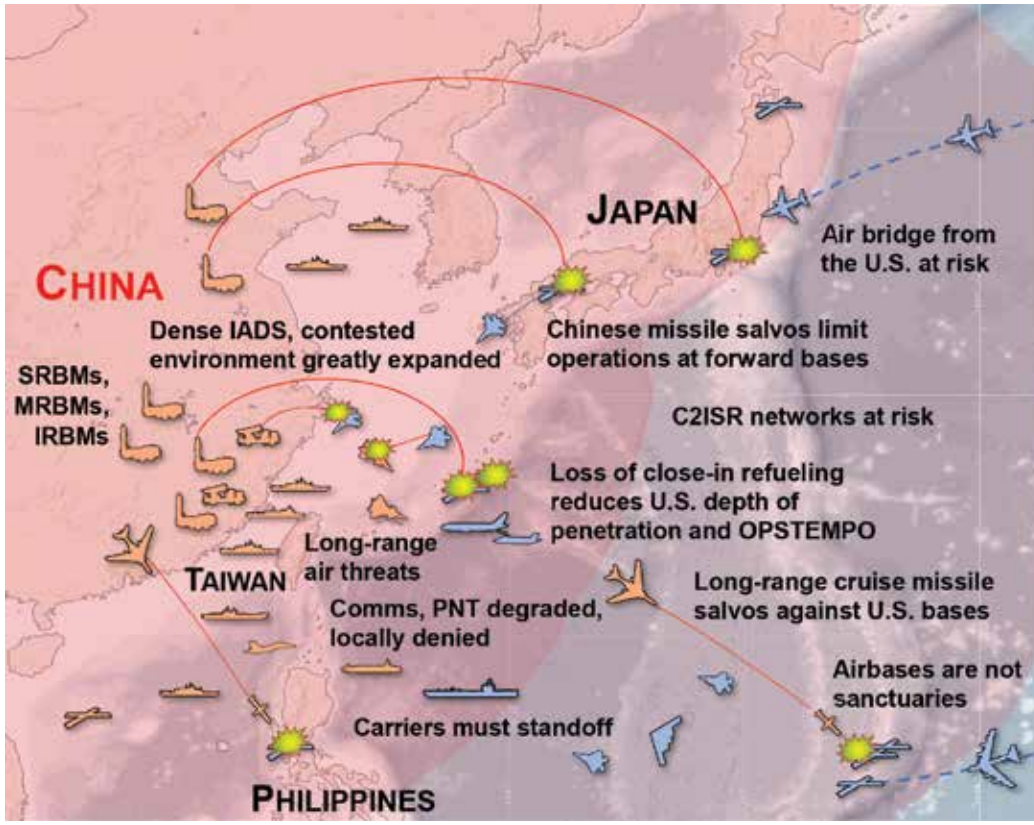
182 U.S. Government Accountability Office (GAO), *Weapon Systems Cybersecurity: DoD Just Beginning to Grapple with Scale of Vulnerabilities* (Washington, DC: GAO, October 2018), available at https://www.gao.gov/assets/700/694913.pdf.

183 McArdle, *Victory Over and Across Domains,* p. 9.

United States.[184] Future stealth strategic bombers carrying long-range (greater than 1,000 nm) LACMs would provide China and Russia with the means to attack the United States from multiple directions. A flight of four advanced bombers with eight to sixteen long-range cruise missiles each could launch a coordinated salvo of 32 to 64 LACMs, some of which could carry nuclear warheads. Countering these large salvos would be a significant challenge for the U.S. military.

Illustrative Force Planning Implications for the Air Force

FIGURE 21: ILLUSTRATING PLANNING ASSUMPTIONS FOR AIR OPERATIONS AGAINST A GREAT POWER ADVERSARY



184 "Russia has prioritized the development of advanced cruise missiles capable of holding targets within North America at risk from distances not previously seen. These systems present an increasing threat to North America . . . and the limited indications and warnings likely to be seen prior to a combat launch." General Lori Robinson, Commander U.S. Northern Command and North American Aerospace Defense Command, statement before the Senate Armed Services Committee, February 15, 2018, p. 11, available at http://www.northcom.mil/Portals/28/Robinson_02-15-18%20SASC%20Testimony.pdf?ver=2018-02-15-105546-867.

The Air Force is in the process of changing its future force planning and resource priorities to reduce the gap between its capabilities and the requirements of the *2018 National Defense Strategy*. As it does so, the Air Force should assess concepts and capabilities that would help it shift toward a force that is capable of projecting power in contested and highly contested environments, rather than the permissive threat environments of the past, as illustrated in Figure 21. This final section of Chapter 2 highlights overarching planning priorities that could help the Air Force to create a lethal and survivable force for future great power conflict. Chapter 3 provides more in-depth recommendations for planning priorities that should inform the size and shape of the Air Force's future aircraft inventory.

A renewed focus on planning for great power competition. In line with the *2018 National Defense Strategy*, the Air Force should shift its planning focus toward preparing for long-term peacetime competition with great powers and future operations to defeat the campaign strategies of great power aggressors—including their aggression in the gray zone. Two illustrative great power conflict scenarios are embedded in the force planning construct proposed for the Air Force in Chapter 3. These and other great power conflict scenarios should form a foundation for Air Force assessments of its future aircraft inventory requirements.

Shift toward a force better capable of operating in highly contested environments. The continued maturation of Russian and Chinese A2/AD complexes and their proliferation of modern military technologies to other states and non-state actors will further shrink the margin between what has traditionally been considered "permissive" and "contested" operating environments. In light of this trend, the Air Force should size and shape its aircraft inventory to operate in environments that will be increasingly contested regardless of the size and scale of potential conflicts, including confrontations in the gray zone.

Deter and prepare to counter gray zone aggression. Given recent successful Chinese and Russian gray zone actions, Air Force military planners should assume both will attempt similar actions in the future. The Air Force should develop operating concepts and capabilities and assess regional force posture changes that would better enable its forces to deter aggression in the gray zone. These concepts and capabilities should include options to degrade Chinese and Russian reconnaissance-strike networks that provide cover for their gray zone actions without escalating gray zone engagements to major conflicts.

Defend the sources of airpower: America's theater airbases. The Air Force's theater airbases lack sufficient active and passive defenses against high-volume air and missile attacks. This vulnerability would undermine its ability to generate aircraft sorties and operate at high tempos during the critical opening stages of a major conflict with China or Russia. Defending theater airbases will require concepts and capabilities to conduct offensive operations to suppress an enemy's ability to launch air and missile salvos. It will also require active and passive airbase defenses that include kinetic and non-kinetic means to engage a larger number of ballistic missiles, cruise missiles, and other air-delivered weapons. This should be a multi-Service responsibility; the Air Force should no longer assume that another Service will eventually field airbase defenses with sufficient capacity to counter Chinese or Russian salvos.

Advanced stealth will be critical to operating in contested environments. The proliferation of advanced IADS systems increases the Air Force's need for aircraft and weapons that will be capable of operating in contested and highly contested environments. These environments are characterized by advanced air threats and dense, overlapping surface-to-air threats whose locations are largely unknown due to their increased mobility, passive detection capability, and other means of masking their presence. The depth and integration of these threats pose a multi-directional challenge to aircraft and weapons penetrating defended regions. Although specific details are classified and highly technical, stealth is a subset of electronic warfare that entails capabilities and actions to deceive sensors that operate in the electromagnetic spectrum. Advanced stealth will remain a critically important ingredient in a cocktail of survivability techniques including automated mission planning, the use of decoys, electronic attack, and other actions to counter 360-degree air and surface threats. Stealth will remain the price of admission for U.S. aircraft and weapons to conduct operations in future contested and highly contested environments. Air Force aircraft without stealth will increasingly be allocated to conducting operations in permissive environments.

Assume C4ISR networks will be disrupted. The Air Force should not assume its forces will have continuous access to reliable information during great power conflict. Key space, airborne, and surface-based C4ISR infrastructures that enable U.S. long-range power projection will be under persistent and continuous kinetic and non-kinetic attack. The Air Force's future aircraft inventory should increasingly be capable of conducting operations independently of C4ISR battle networks that could be degraded or temporarily denied.

Summary

The strategic and operational shifts outlined in this chapter should inform Air Force requirements for new operating concepts, capabilities, and force structure needed in this era of renewed great power competition. Creating new scenarios for informationized forms of warfare would help create a baseline for planners to assess these requirements for future operating concepts, force structure, and advanced capabilities. These scenarios should include realistic assumptions regarding Russia's and China's evolving military strategies and their A2/AD capabilities, which are specifically designed to prevent timely U.S. and allied interventions into their regions and deny freedom of action in all operating domains.

The remaining chapters in this report will further assess these implications, explore potential new operational concepts to achieve the role of airpower, and recommend aircraft inventory capability and capacity requirements for the future Air Force.

CHAPTER 3

A Candidate Force Planning Construct for the Air Force

The 2018 NDAA requires that this report recommends a force planning construct (FPC) that could guide the development of the Air Force's future aircraft inventory. DoD uses force planning constructs to describe the types, number, and frequency of potential military operations, major CONOPS, and other assumptions its Military Departments and other components should use as they assess their future force structure and capability requirements.[185] The assumptions and CONOPS associated with FPCs developed by DoD in the 1990s and 2000s are an inadequate foundation for creating the "more lethal, resilient, and rapidly innovating Joint Force" needed in this era of renewed great power competition.[186] Maturing A2/AD complexes that threaten U.S. forces and bases in both Europe and the Indo-Pacific region compel a break with previous constructs intended for more benign operational conditions. Chapter 3 recommends a FPC that is focused on preparing the Air Force to compete, deter, and, if required, conduct operations to defeat the campaign strategies of one or more great power aggressors. Subsequent chapters expand on potential operating concepts and capabilities for major mission areas that could help inform the Air Force's force development decisions.

Force Planning Constructs

Force planning constructs adopted by DoD during the first two decades after the Cold War included scenarios for major regional conflicts and other operations to provide the U.S. military with a foundation to assess force structure and capabilities required to support the *National Defense Strategy*. Major regional conflicts described by these FPCs ranged from

185 For example, FPCs include personnel rotation guidelines for long-term operations and assumptions for reserve component mobilization timing that impact DoD capability and capacity requirements.

186 DoD, *Summary of the 2018 National Defense Strategy of the United States of America: Sharpening the American Military's Competitive Edge* (Washington, DC: DoD, January 2018). p. 1.

conventional operations for rapidly defeating a large ground force invading a U.S. regional ally or partner to irregular warfare operations on a scale that approached a major conflict level of effort (see Table 14).[187] The 1997 QDR added a requirement to consider force structure and capability requirements for multiple, simultaneous smaller-scale contingency operations that could be of long duration, such as Operations Northern and Southern Watch to enforce no-fly zones in Iraq in the 1990s and early 2000s.

TABLE 14: DOD FORCE PLANNING CONSTRUCTS 1993–2012

	1993 BUR	1997 QDR	2001 QDR	2006 QDR	2010 QDR	2012 Strategic Review
Force planning construct	**2 MRCs, Building Block Construct**	**Sustain the Bottom-Up Review**	**"1–4–2–1"**	**"Refined" Wartime Planning Construct**	**No Name**	**No Name**
Major elements	Defeat 2 regional aggressors nearly simultaneously	Defeat large-scale, cross-border aggression in 2 theaters in overlapping timeframes + Conduct smaller-scale contingencies	Homeland defense + Forward defense in 4 priority theaters + 2 swift defeats (win one conflict decisively)	Homeland defense + 2 conventional contingencies or 1 conventional contingency + 1 large-scale irregular warfare contingency	Homeland consequence management events + 2 large-scale land campaigns or 1 large air/naval campaign + a campaign in a 2nd theater or 1 large land campaign + a long-term, large-scale irregular warfare campaign	Homeland defense, provide support to civil authorities + 1 full combined arms campaign across all domains + Deny objectives or impose unacceptable costs on a second opportunistic aggressor
Major shifts or key points	• Size for 2 MRCs • Most othe contingencies are lesser included cases	• Size for 2 major theater wars plus steady-state SSCs • Swing some forces to 2nd major conflict	• Emphasize forward defense • Accept risk in a 2nd major theater conflict	• Shift capabilities to address 4 focus areas* • Long-duration irregular warfare • Address steady-state and surge demand for forces	• Size as well as shape the force • Multiple near- and far-term scenario cases • Address surge and steady-state demand for forces, including for long-duration irregular warfare	• Do not size the force for large and protracted stability operations • Rebalance to the Asia-Pacific region

*The 2006 QDR established four overarching priorities for DoD's strategic planning and future force development: defeat terrorist networks, defend the homeland in depth, shape the choices of countries at strategic crossroads, and prevent hostile states and non-state actors from acquiring or using WMD.

DoD force planning constructs since the 2001 QDR have included homeland defense operations that required temporary force "surges" in the event of a major disaster or attack on the U.S. homeland. Constructs developed during the 2006 and 2010 QDRs added scenarios for a large-scale irregular warfare campaign, reflecting DoD's near-term need to adequately size

187 For a more complete summary of the evolution of DoD force planning constructs since 1990, see Gunzinger, *Shaping America's Future Military*; and Gunzinger, Clark, Johnson, and Sloman, *Force Planning for the Era of Great Power Competition*.

and shape the Joint Force for operations underway in Iraq, Afghanistan, and against terrorist groups in other regions.

DoD's unclassified summary of the *2018 National Defense Strategy* outlines its shift toward developing a future Joint Force that is more lethal, survivable, and capable of engaging in great power competition over the long-term. While details released to the public are limited, the Strategy's force planning construct requires DoD force providers to prepare for peer-to-peer conflict while maintaining sufficient additional force capacity to deter a second opportunistic aggressor, sustain strategic deterrence, and defend the homeland.

> In wartime, the fully mobilized Joint Force will be capable of: defeating aggression by a major power; deterring opportunistic aggression elsewhere; and disrupting imminent terrorist and WMD threats. During peace or in war, the Joint Force will deter nuclear and non-nuclear strategic attacks and defend the homeland.[188]

A Recommended Force Planning Construct for the Air Force

Similar to the *2018 National Defense Strategy*, the force planning construct outlined in Table 15 recommends the Air Force shift toward preparing for peer-to-peer conflict rather than scenarios reminiscent of Operation Desert Storm. The FPC also requires the Air Force to assess requirements for an additive layer of forces to deter attacks on the U.S. homeland and to sustain the nation's strategic deterrence posture when joint forces are engaged in one or more major conflicts abroad.

For reasons explained later in this chapter, the candidate FPC recommends the Air Force should primarily size and shape its future aircraft inventory to sustain strategic deterrence, defend the homeland, and support joint operations against two great power aggressors nearly simultaneously. The construct assumes that, in the absence of a major peer-to-peer conflict, the resulting forces would have sufficient capacity to engage in long-term competition—including in the gray zone—with Russia and China, support counter-terror operations, and defeat one or more lesser regional aggressors. It is likely there will be exceptions to this "lesser-included" assumption for some specialized forces. For instance, long duration counter-terror operations could create additional requirements for some Air Force special operations capabilities and so-called low-density/high-demand systems. To understand these exceptions, a force that is sized and shaped for scenarios and mission areas listed in the three light blue rows in Table 15 should then be assessed against other potential operations as suggested by the last three rows in Table 15 to determine if the Air Force may require additional force capacity.

The following sections describe in greater detail each of the additive force structure layers in Table 15.

188 DoD, *2018 National Defense Strategy*, p. 18.

TABLE 15: CANDIDATE FORCE PLANNING CONSTRUCT FOR THE AIR FORCE

Primarily shape and size the force to support these mission areas and conflict scenarios	Description
Sustain strategic deterrence	• Includes air forces withheld from deployments to support strategic deterrence during great power conflict
Defend the U.S. homeland	• Homeland defense missions include aerospace control and other air operations to deter or counter opportunistic aggression against the homeland; this includes during conflict with one or more great powers • Homeland defense also includes the Air Force's support to civil authorities in the event of a catastrophic event in the U.S. homeland
Conduct operations as part of the Joint Force to defeat major acts of aggression by China and Russia nearly simultaneously	• Example scenario: Conflict to defeat a major Chinese act of aggression in the Indo-Pacific region • Example scenario: Conflict with Russia to defend or secure the sovereignty of an Eastern European NATO ally • A major conflict with China or Russia could be preceded by Chinese or Russian gray zone aggression that escalates to high-end warfare
Then assess the resulting force to determine if it is sufficient to support the following scenarios and mission areas	**Description**
Conflict with a regional aggressor	• Example: Countering aggression by Iran or North Korea
Long-term peacetime competition	• Includes a level of effort over time to deter or counter great power aggression in the gray zone that falls short of outright conflict
Counter-terror operations	• A level of effort to sustain multiple small and widely dispersed counterterror operations over time that require rotational forces

Sustain Strategic Deterrence

According to the Air Force, sustaining a credible, secure, and reliable nuclear enterprise to deter attacks on the United States and its allies is its highest priority. The Air Force maintains three wings of Minuteman III ICBMs, nuclear weapons-capable B-52H and B-2 bombers, and a limited number of dual-capable fighters to meet its nuclear deterrence requirements. The U.S. triad is supported by Air Force air refueling tankers and E-4B National Airborne Operations Center aircraft that have the mission of maintaining command and control over the nation's nuclear forces in a crisis.[189]

The recommended FPC requires the Air Force to maintain an additive layer of nuclear-capable bombers, tankers, and other force structure to support its strategic deterrence commitments during conflict with one or more great powers. Maintaining these as additive forces that do not deploy to a theater crisis will reduce the potential risk that a great power adversary would seek to take advantage of the U.S. military's engagement elsewhere to attack the U.S. homeland. Chapters 6 and 7 make more specific recommendations on force structure needed to sustain strategic deterrence in the event of one or more great power conflicts.[190]

189 The Air Force also operates a fleet of rotary-wing utility aircraft to support operations of its three Minuteman III wings.

190 Actual U.S. Strategic Command requirements for force withholds are classified.

Defend the U.S. Homeland

Similar to the *2018 National Defense Strategy*, the candidate force planning construct would require that the Air Force organize, train, and equip forces to defend the U.S. homeland and its overseas territories. Major Air Force homeland defense missions could include aerospace control operations to defend U.S. airspace against unauthorized aircraft and airstrikes; airborne operations to deter and defend against a limited number of cruise missile attacks during peer-to-peer conflict; and airlift and other support operations to help civilian authorities manage the consequences of a major attack or catastrophic incident in the U.S. homeland. Chapter 6 summarizes force structure recommendations for potential Air Force homeland air sovereignty and cruise missile defense operations.

Defeat Great Power Aggression

The recommended force planning construct requires the Air Force to organize, train, and equip forces to defeat Chinese and Russian acts of aggression nearly simultaneously. This section describes illustrative scenarios for future great power conflicts used during CSBA's study to assess potential Air Force aircraft inventory requirements. This section also addresses key assumptions such as scenario timing, degree of overlap, and other factors that would have a significant impact on the size and shape of the Air Force's future force structure.

Future Scenarios for Great Power Conflict

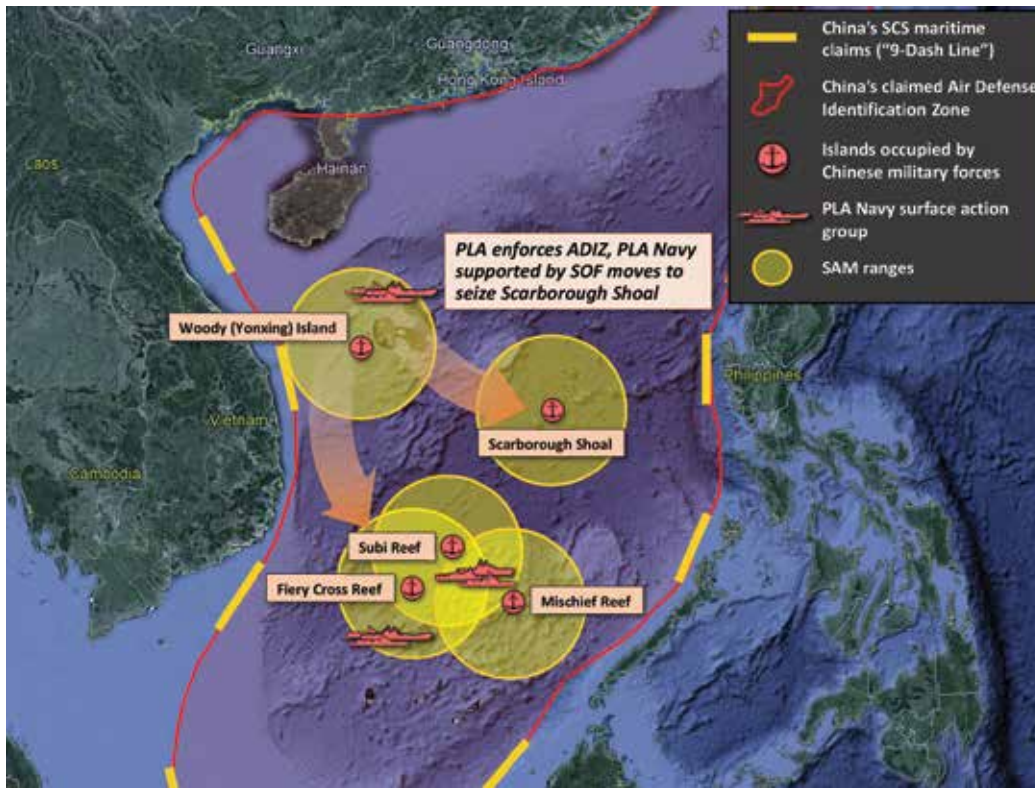
It is unrealistic to require every Service to prepare to support every possible conflict scenario or combination of scenarios that could occur in the future. This is a major reason why the Services identify likely "pacing" threats and scenarios that will best stress their particular forces and capabilities.[191] CSBA created two Air Force pacing scenarios for the purposes of this study: one that is focused on defeating a Chinese act of aggression in the Indo-Pacific region, and a second focused on defeating Russian aggression against a NATO ally in Eastern Europe. Workshops with a mix of military and civilian defense experts developed specific assumptions for each scenario, which were then used to develop recommendations for the Air Force's future aircraft inventory. The scenarios were set in the year 2035 to allow a more complete assessment of new aircraft, advanced munitions, and other capabilities that are projected to join the operational force by then.

Pacing scenario: Future conflict with China in the South China Sea. The Indo-Pacific scenario developed to support this analysis was based on defeating a Chinese military force intent on taking advantage of the U.S. military's engagement in Europe to establish

191 Secretary Wilson described the Air Force's pacing challenge during testimony to the Senate Armed Services Committee: "Currently, when we look at a peer threat, Russia is very strong. China is modernizing very rapidly. And when we project into the 2025–2030 timeframe, our pacing threat we believe is China." Secretary of the Air Force Heather Wilson, "Hearing to Receive Testimony on United States Air Force Readiness," testimony to the Senate Armed Services Committee, Subcommittee on Readiness and Management Support, October 10, 2018, pp. 59–60, available at https://www.armed-services.senate.gov/imo/media/doc/18-62_10-10-18.pdf.

military dominance over areas of the South China Sea, which is claimed by China as its sovereign territory (see Figure 22).

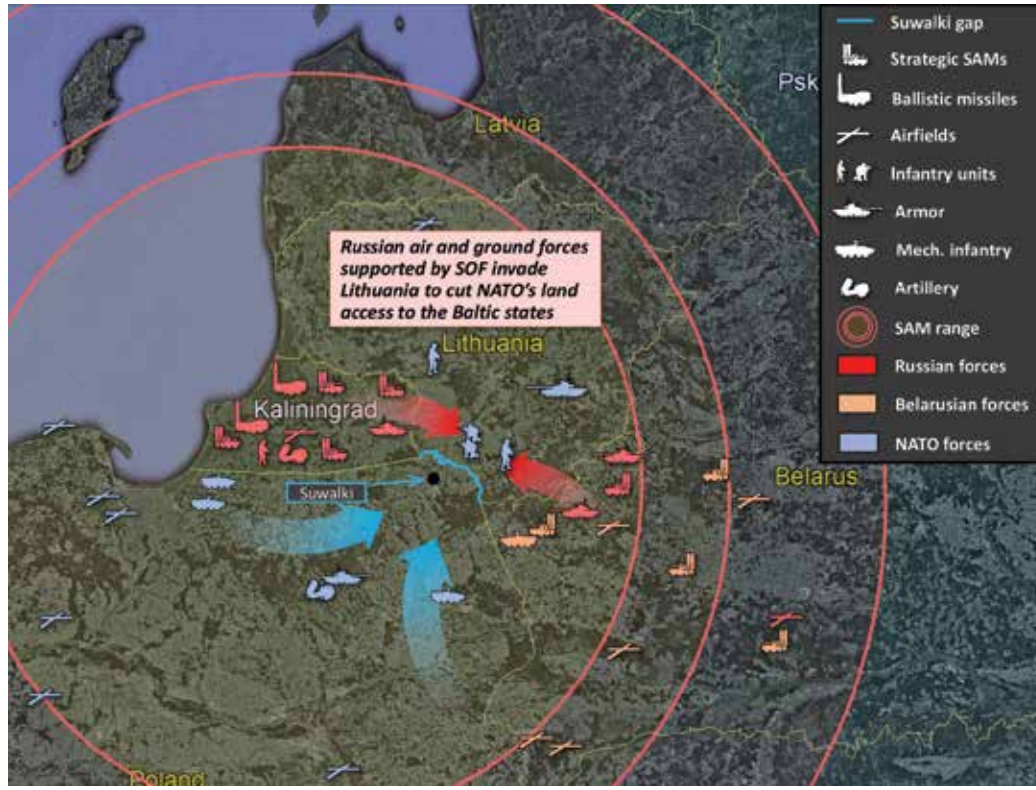
FIGURE 22: FUTURE SCENARIO FOR CHINESE AGGRESSION IN THE SOUTH CHINA SEA



The scenario assumes China would precede its SCS military aggression with gray zone activities in the ECS and information operations designed to intimidate and coerce Japan, the Republic of the Philippines, and other regional allies and partners to deny support to a U.S. military intervention.

Pacing scenario: Russian military invasion into the Baltic states. The European scenario centers on defeating the campaign strategy of a Russian force that invades Lithuania in order to secure a land bridge between Belarus and Russia's Kaliningrad exclave, and cut NATO's air, sea, and land lines of communication to the Baltic states (see Figure 23). The scenario assumes that Russia would complement its invasion with kinetic and non-kinetic attacks against NATO bases, ports, networks, space-based assets, and other capabilities that could delay a NATO response. The scenario also assumes that Russia would precede its attack with gray zone activities across Europe that could include information operations designed to split NATO's unity and complicate its initial response to the building crisis.

FIGURE 23: FUTURE SCENARIO FOR RUSSIAN AGGRESSION IN THE BALTIC REGION



Size and Shape the Future Air Force for Two Nearly Simultaneous Great Power Conflicts

The candidate FPC would require the Air Force to assess requirements for a future force capable of supporting joint operations to defeat the campaign strategies of two great power aggressors nearly simultaneously. The requirements are based on assumptions regarding the character of the potential conflicts, their respective operating environments, and the kinds and numbers of forces that theater commanders would likely request to defeat Russian and Chinese aggression. Moreover, because any candidate FPC should drive the Air Force to field an inventory of systems with the aggregate capability and capacity to deter or defeat the most stressing threats that the United States could plausibly confront, CSBA did not assume that potential adversaries would severely restrict their hostile activities in the hope of avoiding a significant U.S. and ally response—an overly sanguine planning assumption that would perpetuate existing Joint Force vulnerabilities and could increase the likelihood of deterrence failure and operational defeat.

A U.S. military response to defeat Chinese aggression in the South China Sea would predominately consist of naval, air, space, cyber, and Marine Corps expeditionary forces. Forces and capabilities provided by the U.S. Army would likely play significant roles in defending regional bases against Chinese air and missile attacks, conducting electronic warfare operations,

supporting limited SOF operations against Chinese occupied islands in the South China Sea, and launching a limited number of strikes using future long-range, ground-based precision fires. However, participants in this project's workshops and wargame agreed that a South China Sea conflict scenario as illustrated in Figure 22 would not be a pacing challenge for many of the Army's major force elements given the predominately air and maritime nature of the conflict, the vast dimensions of the region that would limit the utility of the Army's current surface-to-surface strike systems, and the limited potential for a large land-based combat operation.

Similarly, a joint force needed to support a NATO Article V operation to defeat a Russian land invasion into the Baltics as illustrated in Figure 23 would predominately consist of land, SOF, air, space, and cyberspace forces. In this scenario, it is highly likely that Air Force capabilities would be tasked to shoulder the preponderance of responsibilities for operations in the air and space domains. Although Navy and Marine Corps expeditionary forces would support multi-domain operations in this scenario, this study assumed that neither Service would be a major contributor to air operations within the immediate Baltic Sea operational area.[192] In the broader European theater, the Navy would be focused on addressing threats posed by Russian bombers and submarines in the Norwegian, Mediterranean, and Black Seas. CSBA did not further consider all potential joint operations in these regions.

For each scenario, air, space, and cyberspace forces and capabilities provided by the Air Force would be critical to defeating great power aggression. Moreover, a joint force capable of credibly deterring a second great power that seeks to take advantage of the U.S. military's engagement in another theater should include sufficient air forces to support a decisive operation rather than a temporary "holding" action. This is particularly important considering that Chinese and Russian forces operating in areas located close to their borders will have significant time and distance advantages over U.S. forces that must surge from distant theaters or homeland garrisons. These advantages could enable a second aggressor to overwhelm a temporary holding operation and achieve a *fait accompli* before sufficient U.S. forces could arrive in theater to prevent it. Should this occur, the level of effort required to then roll-back Chinese or Russian forces that have had time to consolidate and reinforce areas they have occupied could lead to a major escalation of the conflict.

Scenario Timing and Simultaneity Assumptions

Based on insights developed during the workshops, the candidate FPC assumes the United States would receive up to seven days of unambiguous warning of a major Chinese military action in the South China Sea and up to five days of unambiguous warning of a Russian invasion of one or more Baltic states. For the purposes of this study, the FPC assumes there would

192 To cite an example, it is likely that the Navy would be tasked to conduct some standoff cruise missile strikes against appropriate fixed targets in the Baltics region. The Navy's carrier airwings could conduct wide area maritime surveillance and counterair operations in the northern approaches to the United Kingdom and other NATO states to defend against Russian bomber sorties.

be approximately ten to twenty days between D-Days for the two conflicts. Regional subject matter experts participating in the workshops added the perspective that China and Russia learned from Operation Desert Storm that giving the United States and its allies months to build up a massive force in theater is a recipe for disaster. In such a case, Russia or China would likely swiftly move to take advantage of the U.S. military's engagement in another theater instead of allowing the U.S. time to swing forces between regions.

Assumptions for Theater Airbases and Air Force High-Value Aircraft Operations

Participants in CSBA's workshops developed assumptions for airbase operating conditions in the Indo-Pacific region and in Europe for the future conflict scenarios. Participants assumed that operations at airbases along and within the Western Pacific's First Island Chain, in Eastern Europe, and in Scandinavia could be severely degraded by high-volume air and missile attacks during the opening stages of conflict. The ability of these bases to generate Air Force aircraft sorties would likely be minimal, at least in the early stages of conflict before opposing air and missile threats are suppressed.[193] They also assumed that airbases elsewhere in Europe and the Western Pacific could be subjected to attacks, although they might be less frequent or lower volume, and therefore relatively less disruptive to U.S. air operations. Only bases well-removed from the joint operating area would enjoy more permissive operating conditions.

Workshop participants recommended that U.S. air refueling tankers and other non-pene- trating, high-value aircraft such as AWACS and JSTARS be prepared to standoff approximately 800 nm from China's coastline and approximately 500 nm from Kaliningrad to reduce the risk of attack by long-range SAMs and fighters armed with long-range air-to-air missiles. Finally, workshop and wargame participants proposed specific theater commander objectives to better define the actions needed to defeat the campaign strategies of China and Russia. All of these assumptions would have a significant impact on the kinds and number of Air Force aircraft that combatant commanders would request to help defeat great power aggression in their theaters.

193 The following descriptions were used by this study to categorize potential airbase operations during the opening stage of a conflict given the projected ability of Russia and China to conduct long-range strikes in 2035 and beyond. Minimal operations bases: Threat environment could preclude U.S. air forces from conducting sustained combat operations. Aircraft postured at these airbases at the start of a conflict may have to disperse to reduce risk of enemy air and missile attacks. Combat operations bases: U.S. air forces may be capable of conducting combat operations and very limited, temporary operations by air refueling tankers and other large footprint aircraft. Permissive operations bases: Low threat of sustained enemy attack, nearly unconstrained operations including theater maintenance and support activities.

Reduced Potential to Swing U.S. Military Aircraft Between Great Power Conflicts

Most DoD post-Cold War FPCs assumed that some number of Air Force aircraft such as bombers, fighters, AWACS, and air refueling tankers would be able to swing from a first MRC to deter or engage against a second regional aggressor.[194] This was a reasonable assumption for warfighting scenarios of the past that were focused on rapidly defeating conventional aggression by a lesser regional power. Joint air forces that could quickly establish air superiority, use their overwhelming dominance in precision strike to rapidly halt invading forces, and perform other missions to rapidly force an enemy to its culminating point could then be redeployed to a second theater of operations. It is highly likely, however, that achieving these objectives during a major conflict with China or Russia will take a far longer period of time. From this perspective, the Air Force should not assume that it will always be able to swing significant numbers of combat, ISR, air refueling, and BMC2 aircraft that are engaged in one peer-to-peer conflict to another theater to deter or defeat aggression by another great power. The recommended FPC therefore assumes that most Air Force aircraft needed for both of its two major conflict scenarios are additive, although there may be exceptions for some mobility and specialized capabilities. This has the effect of increasing the recommended size of the Air Force's future aircraft inventory.

Different Force Mixes Needed for Operations in Different Theaters

This study also assumed that differences in the geostrategic characteristics of the Indo-Pacific region and Europe would have a significant impact on the kinds of forces needed for major conflicts in each theater. Differences in the dimensions of joint operational areas in the two regions, the nature of the conflicts and enemy threat systems, the greater density of airbases in Europe, the potential to operate Air Force aircraft such as F-16 and F-35 fighters at NATO bases that operate similar model aircraft, and other factors would all impact the mix of air forces requested by theater commanders.

Insights on a Future High-Low Force Mix

As illustrated by Figure 8 in Chapter 1, the Air Force's combat aircraft inventory consists of a "high-low" mix of platforms. Maintaining a high-low force mix offers certain advantages. For instance, having sufficient numbers of non-stealth fighters, light strike and manned and unmanned ISR aircraft in the force to support counter-terrorism operations in permissive and semi-permissive environments could help reduce strains on the force and lower Air Force

194 The 1997 QDR assumed that "in the event of two nearly simultaneous major theater wars, certain specialized, high leverage units or unique assets that the United Sates fields in limited numbers—such as bombers, F-117s, standoff jamming aircraft, AWACS, JSTARS, and other C4ISR platforms, selected special operations forces, and some amphibious assault forces—would very likely 'swing' or be redeployed from one theater of conflict or another." DoD, *Report of the Quadrennial Defense Review* (Washington, DC: DoD, May 1997), p. 31.

total operations and support (O&S) costs. O&S costs include the operational cost per flying hour for Air Force aircraft, examples of which are shown in Table 16.[195]

TABLE 16: EXAMPLE AIRCRAFT TOTAL OPERATIONAL COSTS PER FLYING HOUR

Air Force Aircraft	FY 2017 Operational Cost per Flying Hour Compared to A-10 Cost
A-10	Assume a base cost = 1.0
MQ-9	Cost = 0.25 x base (about 25% of the A-10's Operational Cost per Flying Hour)
F-16C/D	Cost = 1.06 x base
F-35A	Cost = 2.6 x base
F-22	Cost = 3.4 x base

Maintaining a "low-end" force of aircraft, including some number of manned or unmanned future light attack/reconnaissance fighters that cost less to procure and operate relative to 5th and 6th generation aircraft, could increase the number of cockpits available for the crew force. This might help mitigate the Air Force's now-chronic shortage of pilots, which has been caused in part by pilots leaving the force due to the lack of available cockpits. It would also help the Air Force crew force build valuable airmanship skills that could reduce the time needed to transition pilots to higher performance aircraft. Moreover, a balanced high-low force mix would reduce the need to use F-22s, F-35As, and future advanced systems for operations in permissive environments. This could increase the number of high-end forces available and ready to do what they were designed to do—survive and fight in contested environments.

One disadvantage of maintaining a low-end force is the potential reduction in capabilities and force capacity suitable for operations in contested and highly contested environments. However, existing capabilities such as 4th generation and upgraded 4-plus generation fighters, UAVs, and new light attack aircraft could perform important roles during conflicts with Russia or China, which are addressed later in this report. Another potential disadvantage is the cost in dollars and other resources, including additional facilities and maintenance personnel, that are needed to sustain a larger number of different weapon systems.

Although it is practical to assume the Air Force will always have a high-low force, this does not mean the ratio of high-low aircraft in its inventory should remain static over time. It is highly likely that operating environments that are assumed to be permissive today will become increasingly non-permissive as advanced air defense systems and other threats to air operations continue to proliferate. As this trend continues, the Air Force should be prepared to adjust its force mix to ensure it avoids a growing shortfall in high-end aircraft.

195 Based on Air Force Total Cost of Ownership (AFTOC) data for FY 2017 provided to CSBA by the Air Force. Multipliers are used in Table 16, since the actual costs in dollars are Unclassified/For Official Use Only.

Other Study Assumptions

The 2018 NDAA requires this report to address "current and projected capabilities of other Armed Forces that could affect force structure capability and capacity requirements of the Air Force" and "alternative roles and missions for the Air Force." This section addresses study assumptions related to other force providers, the Air Force's roles and missions, and the availability of precision-guided munitions that would likely be needed in future air operations.

Assumptions Regarding Contributions of Other Force Providers

Capabilities deployed to joint and combined operations by other force providers, including the Navy, Army, Marine Corps, U.S. Special Operations Command, and U.S. allies and partners could reduce or increase some future requirements for Air Force aircraft. For instance, future ground-based, long-range artillery supported by UAVs organic to the U.S. Army or allied forces could help suppress Russian strategic SAMs located in Kaliningrad and Belarus. Ground-based electronic warfare systems, ISR networks, and long-range surface-to-surface cruise and ballistic missiles could play significant roles during great power conflicts in the Indo-Pacific and Europe. Similarly, ISR, BMC2, precision fires, and other capabilities provided by the Navy and Marine Corps also affect future Air Force requirements. All three of these examples could reduce future requirements for Air Force aircraft. In contrast, if the U.S. Army adopts a posture that increases its demand for strategic and tactical airlift, future Air Force requirements could increase.

There is, however, a great deal of uncertainty regarding relevant factors such as the acquisition timing for other Services' future capabilities and their potential to be postured in Europe and the Indo-Pacific region as part of DoD's future "contact" or "blunt" force layers.[196] Similarly, there is uncertainty regarding the willingness and ability of some U.S. allies and partners to contribute to future combined operations against China and Russia. Due to these uncertainties, aircraft inventory recommendations in this report assume capabilities provided by other force providers are additive and complementary, and thus would not decrement potential requirements for the Air Force's future aircraft inventory.

Assumptions Regarding Future Air Force Roles and Missions

The candidate force planning construct described in this chapter and recommendations made in following chapters assume the Air Force will continue to organize, train, and equip forces for roles and missions currently required by the United States Code Title 10 and DoD directive 5100.1.

196 The *2018 National Defense Strategy* briefly summarizes these layers as part of DoD's new Global Operating Model: "The Global Operating Model describes how the Joint Force will be postured and employed to achieve its competition and wartime missions. . . . It comprises four layers: contact, blunt, surge, and homeland. These are, respectively, designed to help us compete more effectively below the level of armed conflict; delay, degrade, or deny adversary aggression; surge war-winning forces and manage conflict escalation; and defend the U.S. homeland. DoD, *2018 National Defense Strategy*, p. 7.

According to Title 10 of the United States Code, the Air Force:

> shall be organized, trained, and equipped primarily for prompt and sustained offensive and defensive air operations. It is responsible for the preparation of the air forces necessary for the effective prosecution of war except as otherwise assigned and, in accordance with integrated joint mobilization plans, for the expansion of the peacetime components of the Air Force to meet the needs of war.

DoD Directive 5100.1 more explicitly describes the Air Force's major functions, which include preparing to conduct air and missile defense operations, global precision attack operations, close air support operations, air superiority operations, global integrated ISR operations, and "nuclear operations in support of strategic deterrence."[197] The Air Force's future operating concept describes the evolution of its core missions that are consistent with Title 10 of the U.S. Code and DoD Directive 5100.1 (see Table 17).[198]

TABLE 17: EVOLUTION OF THE AIR FORCE'S CORE MISSIONS

1947	Today	Future
Air superiority	Air and space superiority	Adaptive domain control
Air reconnaissance	Global integrated ISR	Global integrated ISR
Airlift mobility	Rapid global mobility	Rapid global mobility
Strategic air force	Global strike	Global precision strike
Coordination of air defense	Command and control	Multi-domain command and control

This report makes two recommendations for the Air Force's future responsibilities. The first addresses the Air Force's role in defending its theater airbases that could be subject to major air and missile attacks, which is addressed in greater detail in Chapter 7. The second recommends the Air Force continue to assess roles and missions of the Services and across the Department of Defense as multi-domain operations and other new joint operating concepts develop and mature.

Assumptions on DoD's Future Munitions Inventory

Similar to other U.S. Government and non-government studies, this assessment concluded that DoD munitions inventories have major shortfalls. Significant strategic vulnerabilities have resulted from cuts to PGM acquisition programs to realize savings or to resource other Service and DoD priorities. This situation is further complicated by a U.S. defense industrial

197 The full text of Air Force functions contained in the latest version of DODD 5100.1 are listed in Appendix xx. "Functions of the Department of Defense and its Major Components," DoD Directive 5100.1, December 21, 2010, p 34, available at https://fas.org/irp/doddir/dod/d5100_01.pdf. For a brief history of the evolution of Air Force functions since 1947, see John T. Correll, "A New Look at Roles and Missions," *Air Force Magazine*, November 2008, available at http://www.airforcemag.com/MagazineArchive/Pages/2008/November%202008/1108roles.aspx.

198 U.S. Air Force, *Air Force Future Operating Concept* (Washington, DC: Headquarters, U.S. Air Force, 2015), p. 12, available at https://www.af.mil/Portals/1/images/airpower/AFFOC.pdf. The Air Force intends to continue to extend the scope of these five core missions over time in order to adapt to the development of advanced technologies and new operational concepts. Ibid., p. 11.

base that lacks sufficient excess capacity to quickly surge the production of air-to-surface and air-to-air munitions to support even a single large-scale military operation. Due to the magnitude of the issue and the Congressionally directed focus of this study on *aircraft* inventory requirements (as opposed to munitions), the workshops and wargame used to assess aircraft inventory requirements assumed there will be a sufficient number of munitions to support future operations. The following chapters do, however, make recommendations on the kinds and characteristics of advanced weapons needed to support future operational concepts for U.S. air forces posed by this report.

Summary

This report recommends a candidate force planning construct the Air Force could use as a baseline to assess its future aircraft inventory requirements. Similar to the *2018 National Defense Strategy*, the candidate FPC is intended to help shift Air Force planning toward preparing to defend the U.S. homeland, sustain strategic nuclear deterrence, and prepare for potential great power conflict in the future. Unlike the *2018 National Defense Strategy,* the candidate construct recommends the Air Force assess force structure and capability requirements to support joint operations to defeat the campaign strategies of two great power aggressors nearly simultaneously. This assumption is based on three factors: the projected nature of future operating environments in the Indo-Pacific and Eastern Europe, the need for joint force capabilities that can quickly respond to deter or defeat a second great power attempting to take advantage of the U.S. military's engagement with a great power in another theater, and the characteristics of surge forces needed to blunt attacks that could occur with little warning. Finally, the candidate construct assumes few U.S. air capabilities—from any Service—will be able to disengage from a major fight with one great power to swing to a fight with a second great power. Breaking with this post-Cold War assumption, fundamental to all previous post-Cold War FPCs increases the required Air Force aircraft inventory.

CHAPTER 4

Concepts and Capabilities for Future Air Force Counterair Operations

DoD joint doctrine defines air superiority as the degree of control of the air that would allow a force to conduct operations at a given time and place without prohibitive interference from an adversary's air and missile threats.[199] The ability to control the air has long been an asymmetric advantage for the United States. Control of the air provides freedom from attack, freedom of access, freedom of awareness, and freedom to attack through the air domain, all while denying an adversary use of the air to do the same. Chapter 4 summarizes insights on potential counterair concepts and capabilities that were developed by teams of experts from the U.S. military and civilian defense community acting as air planners during workshops and a wargame based on the illustrative scenarios described in Chapter 3. It begins with descriptions of operational concepts developed by the teams for airbase defense, airborne sweeps, escorts, and other counterair operations. It then summarizes insights on capabilities and force structure that may be needed for future Air Force counterair operations in contested and highly contested environments.

The Air Force describes the counterair mission as integrated defensive and offensive operations in all domains to obtain and maintain a desired degree of air superiority.[200] Defensive counterair (DCA) operations consist of active and passive tasks to protect friendly forces and vital interests from enemy airborne attacks.[201] Active DCA tasks include operations to defend

199 CJCS, *DoD Dictionary of Military and Associated Terms*, Joint Publication 1-02 (Washington, DC: DoD, August 1, 2017), p. 13, available at http://dtic.mil/doctrine/new_pubs/dictionary.pdf.

200 CJCS, *Countering Air and Missile Threats*, Joint Publication 3-01 (Washington, DC: DoD, May 2, 2018), p. 3, available at https://www.doctrine.af.mil/Doctrine-Annexes/Annex-3-01-Counterair-Ops//.

201 Ibid., pp. 23–25.

against or mitigate attacks by enemy manned or unmanned aircraft and missiles. Passive operations such as camouflage, deception, hardening, dispersion, mobility, and other countermeasures minimize the effectiveness of air and missile threats against friendly forces and assets.

Offensive counterair (OCA) operations seek to destroy, disrupt, or degrade enemy air capabilities by engaging them as close to their point of launch as possible, ideally before they are launched against friendly forces.[202] OCA operations are normally conducted over enemy territory with the intent to increase the U.S. military's freedom of action and degrade an enemy air force's offensive potential. OCA is subdivided into four different types of operations: sweeps, escorts, attack operations, and the suppression of enemy air defenses. Sweep operations seek out and destroy enemy aircraft or targets of opportunity in designated areas in order to deny freedom of action to enemy air forces and cause them to expend resources for defensive rather than offensive purposes.[203] Escort operations protect friendly aircraft penetrating enemy territory from air-to-air and surface-to-air threats. Attack operations destroy, disrupt, or degrade counterair targets on the ground to prevent enemies from employing their offensive air and missile assets. SEAD operations use disruptive or destructive means to degrade, neutralize, or destroy enemy surface-based air defenses.[204]

Challenges to the U.S. Military's Control of the Air

Over the last three decades, China and Russia have developed operating concepts and capabilities to prevent the U.S. military from gaining and maintaining control over the air domain. Both possess ways and means to attack the entire chain of U.S. air operations, from airbases that U.S. forces depend on to generate aircraft sorties to ISR, BMC2, and other capabilities needed to conduct air missions (see Figure 24).

The Russian and Chinese militaries understand the most efficient way to attack an opposing air force is to kill its aircraft at their airbases. Both now have the ability to attack U.S. airbases with salvos of ballistic missiles, cruise missiles, and other weapons that can be launched from the ground, air, sea, and undersea. U.S. airbases in Europe and the Indo-Pacific region lack sufficient hardened facilities, decoys, missile interceptors, and other active and passive defenses against large salvos of guided weapons. Major air and missile attacks on these airbases would have a devastating effect on the Air Force's ability to conduct air campaigns, including operations to control the air domain. China and Russia have kinetic and non-kinetic means to threaten the logistics infrastructure needed to sustain U.S. and allied air operations, much of which has been optimized to maximize their efficiency in peacetime. These

202 Ibid., pp. 22–23.

203 CJCS, *DoD Dictionary of Military and Associated Terms*, p. 88.

204 Ibid., pp. 22–23.

well-known vulnerabilities create opportunities for Russia and China to indirectly suppress the Air Force's ability to control and exploit the air.

FIGURE 24: COUNTERING EACH LINK IN THE U.S. COUNTERAIR OPERATIONS CHAIN

China and Russia have developed kinetic and non-kinetic means to deceive, disrupt, and attack BMC2 architecture that support the U.S. military's air operations. These defenses can cause U.S. non-stealth BMC2 and ISR aircraft to operate from long standoff distances that significantly degrade or negate their ability to use their sensors and form an accurate picture of the battlespace. Chinese and Russian counter-ISR capabilities integrated with other kinetic and non-kinetic defenses are intended to reduce the effectiveness of aircraft and missiles attacking China's and Russia's airbases. This would, in turn, increase the number of Chinese or Russian aircraft that U.S. air forces must engage in the air. In the future threat environment, Chinese and Russian 4th and 5th generation fighters with highly capable sensors and weapons supported by a robust surveillance architecture will improve their ability to challenge U.S. counterair aircraft.

Denying the air domain to U.S. air forces would improve an adversary's ability to conduct its own offensive air operations and provide protective cover for its military forces and installations located deep in their interiors.[205] In short, failing to achieve a sufficient degree of air

205 Counterspace threats include GPS jammers; laser dazzlers; airborne platforms with electronic warfare and directed energy weapons; ground-based high energy lasers; ASAT missiles; and cyber threats. Joe Gould, "Think Space Force Is a Joke? Here Are Four Major Space Threats to Take Seriously," *Defense News*, August 9, 2018, available at https://www.defensenews.com/space/2018/08/09/think-space-force-is-a-joke-here-are-four-major-space-threats-to-take-seriously/.

superiority in contested and highly contested environments will threaten the U.S. military's future ability to conduct offensive and defensive operations in all domains. Absent significant changes to the Air Force's aging force structure, its future ability to control the air in contested and highly contested environments will be greatly reduced.

The following two sections summarize insights on potential counterair concepts and future capabilities that could help maintain the U.S. Air Force's ability to control the air and enable Joint Force operations on land, at sea, in the EMS, and in other warfighting domains.

Insights on Counterair Operations: Future Baltic Sea Region Conflict Scenario

During CSBA's workshops and wargame, a team of experts acting as a U.S. air planning cell developed an overarching concept to attain temporal, localized control of the air domain to enable the Joint Force to project offensive power during a future conflict with Russia in the Baltic Sea region. This concept included establishing a layered air and missile defense-in-depth of U.S. airfields located in contested environments and conducting standoff and stand-in (penetrating) offensive operations to establish the needed degree of air superiority in highly contested environments.

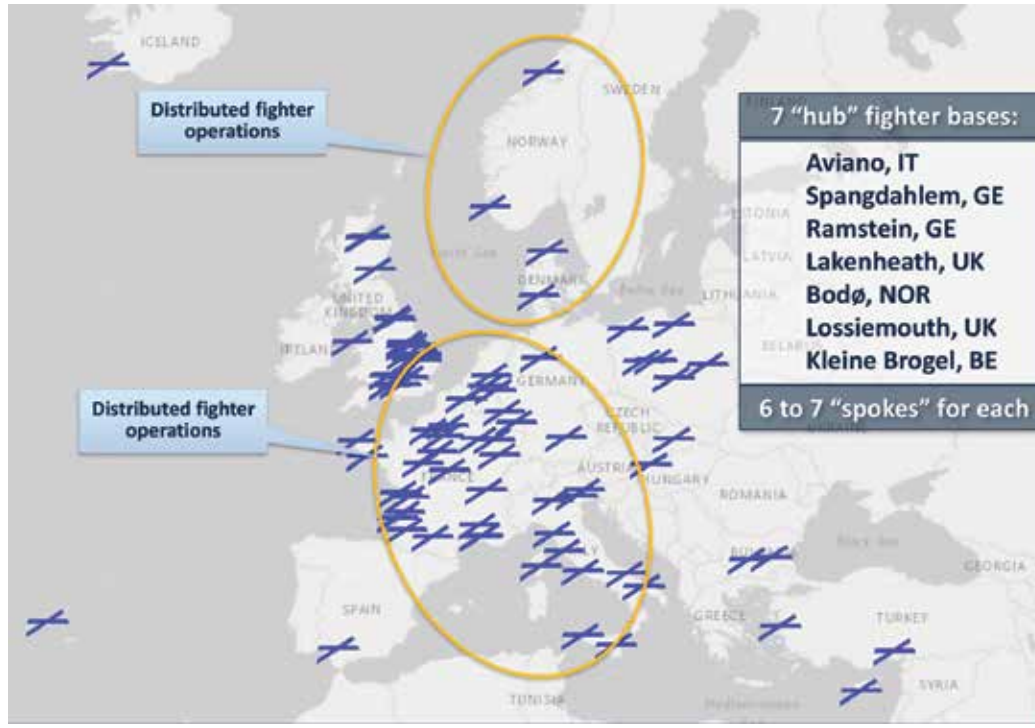
Defensive Counterair Concept: Airbase Defense

The European wargame planning cell assumed a future Russian invasion of NATO states in the Baltic Sea region could be accompanied by ballistic and cruise missile strikes on Western European airbases hosting U.S. and NATO aircraft. Russia would likely complement these strikes with non-kinetic (cyber and electronic warfare) and SOF attacks on base infrastructure critical to generating U.S. and NATO aircraft sorties.

To reduce the risk of attack, the wargame team dispersed their fighter forces at airfields located across Western Europe and postured their bombers, tankers, and other large aircraft at even greater distances from Russian surface-to-surface fires. As shown in Figure 25, a hub-and-spoke approach was used to beddown U.S. fighter forces in Europe and reduce resources needed for defensive counterair missions. Each of the seven hub airbases were hardened with a mix of active and passive defenses against air and missile attacks. Individually, hub bases would have resources to support distributed air operations at multiple spoke airfields.[206]

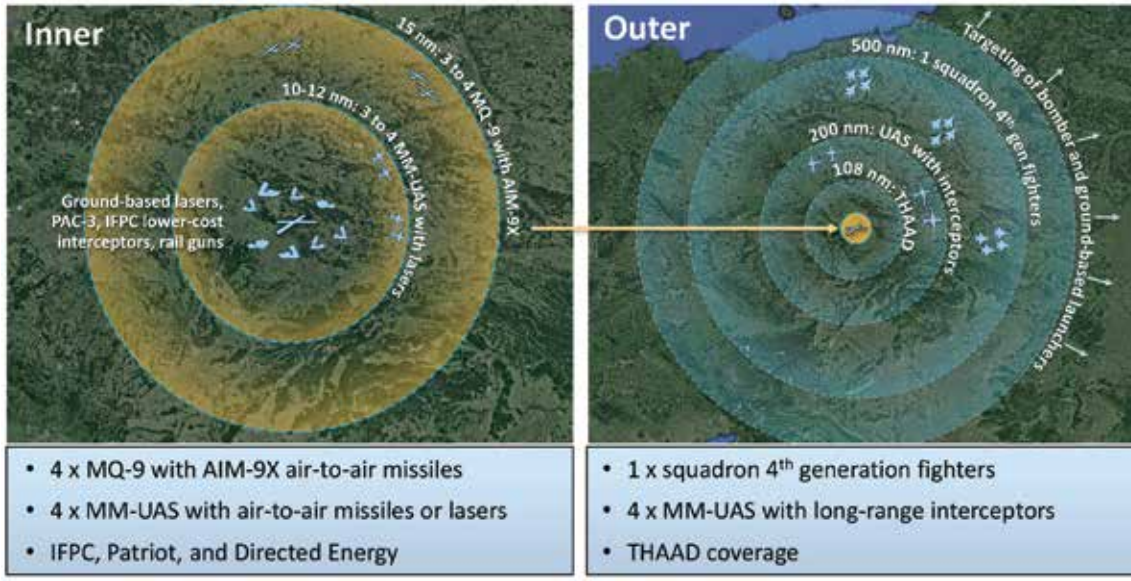
206 The team assumed Air Force aircraft would have permission to transit and operate in Swedish and Finnish airspace.

FIGURE 25: INITIAL EUROPEAN COUNTERAIR BASING POSTURE



The team also recommended creating a layered air and missile defense for each of these hub bases. An inner ring of ground-based air and missile defenses located around these airbases could consist of capabilities similar to the Army's Indirect Fire Protection Capability (IFPC) system, Patriot missile batteries, directed energy weapons, and multi-mission UAS with interceptor missiles or high-energy solid-state lasers (see Figure 26). This combination of kinetic and non-kinetic systems would provide a high-capacity, 360-degree short- and medium-range defensive layer against Russian weapon salvos.

FIGURE 26: LAYERED AIRBASE DEFENSE CONCEPT AND CAPABILITIES



In the outer ring, Terminal High Altitude Area Defense (THAAD) batteries would provide a long-range defense against ballistic missiles, and UAS and 4th generation aircraft with air-to-air missiles would fly orbits to counter enemy strike aircraft and cruise missiles.[207] Each defensive layer should have sufficient capacity to engage at least one enemy bomber loadout of cruise missiles. Beyond these inner and outer areas, U.S. penetrating aircraft would take the initiative and target airborne bombers and ground-based missile launchers operating under the cover of Russia's IADS. This emphasis on "shooting the archers" that are attacking NATO forces could proactively reduce the numbers of incoming weapons, or "arrows," that U.S. and NATO inner and outer ring airbase defenses must address.

Protecting U.S. High-Value Airborne Aircraft

U.S. high-value airborne aircraft such as non-stealth BMC2 platforms would likely be constrained to operating approximately 500 nm from Kaliningrad due to ground and air threats located in the Russian exclave. The wargame planning team allocated a modest number of aircraft toward sustaining DCA combat air patrols (CAP) located 150 to 200 nm in front of each high-value airborne asset (HVAA) orbit to counter Russian long-range fighters and other threats.

207 For a discussion of novel higher-capacity and more cost-effective air and missile defenses to defeat salvo attacks, see Gunzinger and Rehberg, *Air and Missile Defense at a Crossroads*.

Escorts, Sweeps, and SEAD Operations in Contested and Highly Contested Environments

At the start of a conflict with Russia, U.S. and NATO forces permanently stationed and deployed in Eastern Europe would need to operate under Russia's A2/AD umbrella. In this case, penetrating sweep and SEAD operations would be necessary in order to protect U.S. forces on the ground until Russian air and surface-to-air threats are reduced. This would require Air Force penetrating counterair forces to conduct DCA operations in a highly contested environment to degrade Russia's ability to conduct air attacks and to provide temporary pockets of air superiority to support U.S. and NATO offensive operations.

Escort operations. The team adopted concepts to defend U.S. standoff and penetrating ISR and strike aircraft from Russian counterair threats. 5th generation fighters were used to escort non-penetrating bombers as they flew to and recovered from weapons launch points located at the outer edges of contested areas. When possible, bombers launched their salvos from within the range of friendly ground-based outer ring air and missile defenses, which provided added protection against Russian air attacks. F-35A fighters armed with future Stand-in Attack Weapons (SiAW) were used in the SEAD role (discussed in greater detail in Chapter 5). Penetrating counterair platforms increased the freedom of action, survivability, and effectiveness of other penetrating platforms and weapons in the highly contested environment.

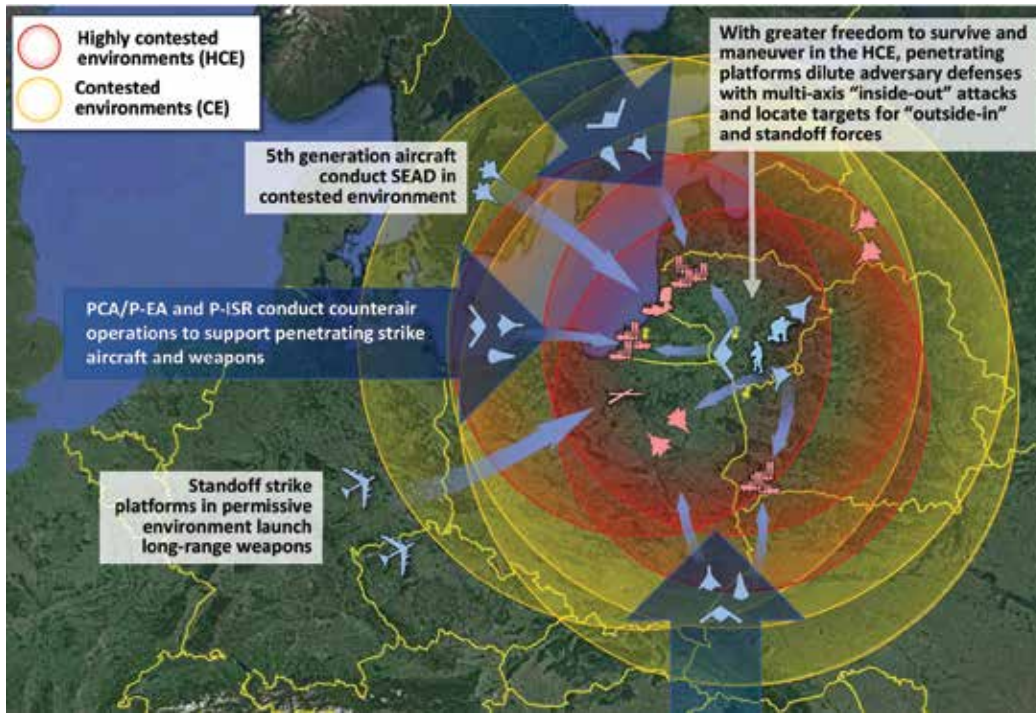
Sweep operations. The team planned to conduct periodic pulses of forces to conduct sweep operations into highly contested environments to disrupt, degrade, or destroy, as necessary, Russia's air forces at or as close to their bases as possible. These operations were intended to deny freedom of maneuver to Russian ISR and strike aircraft and to protect U.S. forces operating under Russia's area-denial umbrella from attacks. Air Force 5th generation fighters would conduct sweep operations throughout the contested environment that extended over much of the Baltic Sea region, supplemented by 4th generation aircraft operating in permissive threat environments. U.S. penetrating counterair aircraft would attack Russian threats inside the highly contested environment from all directions to reduce Russia's ability to concentrate its defensive operations and possibly cause it to allocate more forces toward protecting its rear areas. Counterair sweep targets would include Russian bombers, fighters, helicopters, and ISR platforms in addition to mobility, electronic warfare, C2, and counterspace aircraft. Penetrating U.S. sweep forces with appropriate munitions could also engage Russian ballistic missiles during their vulnerable boost phase.

A future Penetrating Counterair aircraft was the team's primary means of conducting sweep operations for targeting the full range of air threats and to suppress and destroy enemy air defenses using electronic attack and SiAW in highly contested environments. PCA capa- bility attributes prioritized by the team included long mission endurance, the ability to carry a large number of munitions, and a sensor suite to provide a fused operational picture using information from sensors in all domains. Most importantly, PCA aircraft designed to operate in communications degraded and locally denied environments should be capable of independently completing all phases of the find, fix, track, target, engage and assess kill chain.

Suppression of enemy defenses. The wargame planning team also planned to use the PCA aircraft to perform escort, SEAD, and other operations to counter air and surface-to-air threats in the highly contested environmen.[208] In addition to the PCA aircraft, the team considered the need for a separate, dedicated P-EA platform to conduct kinetic and electronic attacks in the highly contested environment. This approach was rejected in favor of a concept to conduct distributed electronic attack operations that used the electronic attack capabilities of other penetrating aircraft, weapons, expendables, jammers and decoys.[209] A future multi-mission PCA/P-EA aircraft should be capable of conducting stand-in electronic attacks as well as other electronic warfare functions in support of this distributed concept.

An effective future offensive and defensive force for counterair operations in the highly contested environment should be a family of capabilities, not a single new fighter or other advanced aircraft. This family should consist of complementary capabilities that operate in multiple domains.

FIGURE 27: MULTI-DIRECTIONAL AIR DOMINANCE OPERATIONS FROM INSIDE AND OUTSIDE A HIGHLY CONTESTED ENVIRONMENT



208 A PCA platform could be a manned or unmanned aircraft, depending on the technical readiness level (TRL) of technologies needed for an autonomous UAS or an RPA to perform lethal air-to-air and SEAD missions in the highly contested environment. Rules of engagement for autonomous use of weapons and assured command and control are also concerns for using UAS or RPAs on a large scale in high-intensity conflicts.

209 For more information on distributed EMS warfare operations, see Clark and Gunzinger, *Winning the Airwaves*; and Clark, Gunzinger, and Sloman, *Winning in the Gray Zone*.

Future air domain capabilities for counterair operations in highly contested environments should include advanced multi-mission platforms that can conduct ISR, strike, air-to-air, and SEAD operations. This family of capabilities could conduct inside-out attacks to stimulate, suppress, and destroy Russian air-to-air and surface-to-air defenses while defending other U.S. forces. Fires from outside of the highly contested environment, supplied by targeting information from penetrating forces, should contribute to these operations. As displayed in Figure 27, multi-axis outside-in and inside-out attacks would cause an enemy to conduct a 360-degree defense, reducing its ability to concentrate its defenses on a single attack vector or against a single penetrating threat.

This multi-directional approach would help improve the survivability and the freedom of maneuver for all U.S. forces operating in contested areas. As Russian defenses are attrited and the operational environment becomes less contested, additional U.S. forces would be able to participate in offensive operations. This would create a cascade of increased firepower that could saturate the defensive capacity of Russian forces.

Insights on Counterair Operations: Future South China Sea Conflict Scenario

Assumptions for Theater Basing and Platform Survivability

China will improve its dense architecture of multi-phenomenology sensors that can now cue its forces to attack U.S. air forces at their airbases and as they operate near and in contested and highly contested air environments. Additionally, the future PLA Navy will likely operate numerous surface action groups, carrier battle groups, and other naval forces that can contest air superiority well beyond the Chinese littorals. In order to conduct effective multi-domain operations, U.S. air forces will need to conduct counterair operations to degrade and attrite China's air forces and air and missile defense capabilities at sea as well in the air and on land. As with the counter-Russia team, the counter-China team developed approaches to gain the requisite levels of air superiority to support joint and combined force operations.

Defensive Counterair Concept: Airbase Defense

The China scenario wargame planning team postured their initial counterair forces at airfields in the Philippines, Japan, the Mariana Islands, Northern Australia, Diego Garcia, and other bases in the central Pacific and Alaska (see Figure 28). Operating from these more remote airbases would help reduce the size of Chinese weapons salvos to within the capacity of layered airbase air and missile defenses. It was assumed that U.S. air forces stationed in South Korea to deter aggression by the Democratic People's Republic of Korea would not be available for operations against China.

FIGURE 28: INITIAL PACIFIC COUNTERAIR BASING POSTURE

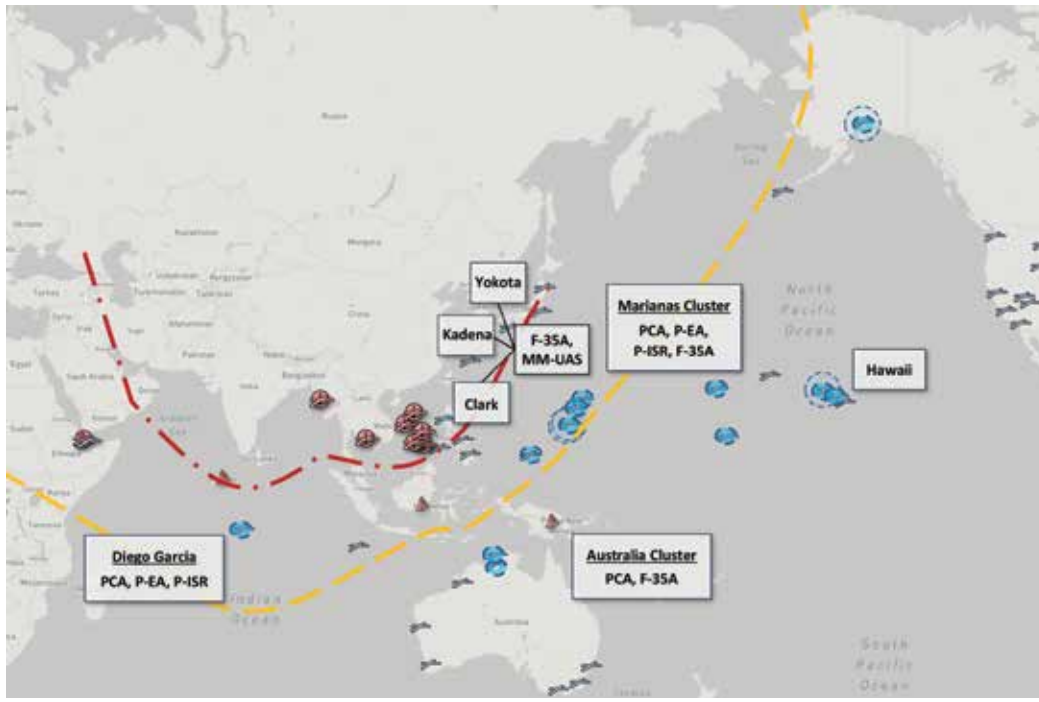
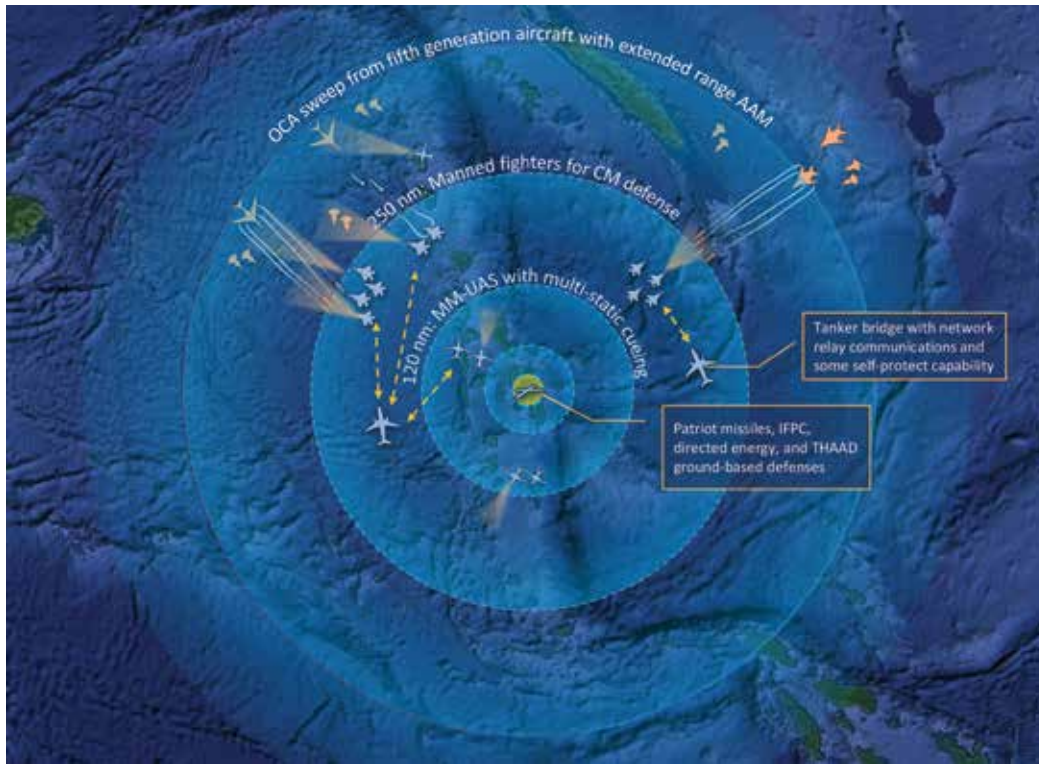


FIGURE 29: LAYERED AIRBASE DEFENSE CONCEPT AND CAPABILITIES



Similar to the European wargame planning team, the Indo-Pacific team developed a concept for a layered airbase defense (see Figure 29). U.S. and allied bases along the First Island Chain were more heavily defended than NATO bases in Western Europe due to China's large inventory of land-attack missiles, and the paucity of available airbases in the Pacific region compared to Europe. In an inner layer of defenses, ground-based air defenses and multi-mission UAS provided high-capacity, continuous, and all-aspect short- and medium-range sensing and defenses.

In addition to active defenses, bases should be heavily hardened and have other passive defense measures. THAAD batteries would provide an outer layer surface-based ballistic missile defense, and UAS and 4th generation aircraft with extended-range air-to-air missiles would fly orbits to detect and attack inbound enemy aircraft and missiles. The concept complements inner and outer layer defenses with robust ground- and air-based sensors and integrated fire control systems.

Of note, Chinese low-observable bombers expected to be fielded in significant numbers by 2035 will pose a major, dual-faceted threat to airbases. H-20 bombers, JH-XX fighter-bombers, and other future advanced aircraft could carry a large capacity of short-range standoff weapons. A large volume of air-delivered weapons could overwhelm U.S. airbase defenses unless the bombers are detected and destroyed before they launch their payloads. This places a premium on creating dense and resilient U.S. networks of surface, airborne, and space sensors to detect and then kill enemy strike aircraft and their BMC2 before they launch their weapons. Future Chinese H-20 bombers could also use longer-range weapons to strike U.S. bases in Alaska, Hawaii, and other locations previously considered to be operational sanc- tuaries. Defeating this new class of long-range aircraft and weapons would require active and passive defenses not only in forward bases, but throughout a theater of operations and possibly at some bases in the United States.

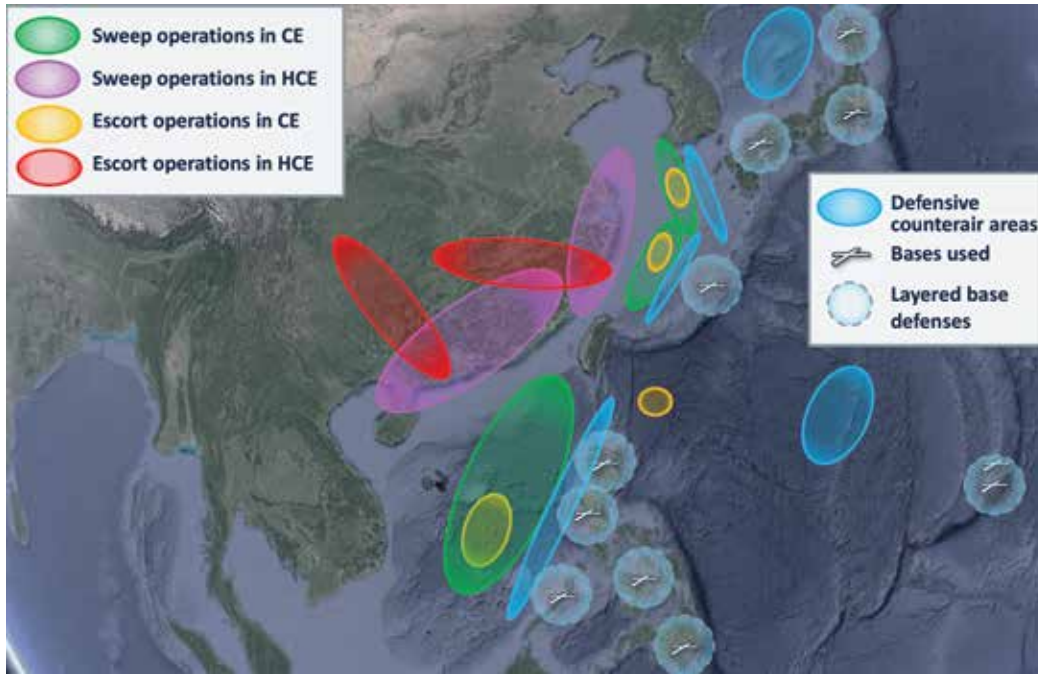
Protecting U.S. High-Value Airborne Assets

Initially, U.S. HVAA, to include aerial refueling tankers, would be constrained to operating no closer than 800–1,000 nm from the Chinese mainland. While HVAA could operate closer to Chinese threats if escorted or operating within a DCA zone, they would still need to maintain standoff distances that could greatly reduce or negate the effectiveness of their sensors and other mission systems.

Escorts, Sweeps, and SEAD Operations

The team developed concepts to escort U.S. bombers and other strike aircraft similar to the European planning team. Figure 30 summarizes the team's counterair approach. In general, Air Force 5th generation aircraft would escort strikes to the outer edges of the highly contested environments, while PCA/P-EA would escort other penetrating aircraft in both the contested and highly contested environments (red ovals).

FIGURE 30: OVERVIEW OF THE TEAM'S COUNTERAIR APPROACH



The blue ovals in Figure 30 illustrate areas that would be defended by U.S. manned aircraft or unmanned combat aerial vehicles carrying extended-range interceptors capable of countering Chinese aircraft and missiles (possibly including hypersonic glide vehicles). The team planned to conduct concentrated sweep operations periodically throughout the contested and highly contested environments. These multi-axis pulses of airpower would attrite enemy bombers and other aircraft, probe Chinese defenses, detect and engage targets of opportunity, and help shape Chinese defensive operations in ways that would be advantageous to allied forces. 5th generation aircraft would conduct these operations in contested environments, and the pene- trating family of capabilities summarized previously would conduct operations in highly contested environments. The green and purple ovals depict sweep operations in contested and highly contested environments, respectively. In permissive and contested environments, 5th generation aircraft would escort HVAA. These include Navy maritime patrol aircraft that are actively prosecuting undersea threats, as shown by the yellow ovals. If available, PCA/P-EA aircraft would also be used for this mission due to their greater mission endurance.

Chapter 5 has additional information on approaches to conduct SEAD/DEAD and offensive counterair strike operations into contested and highly contested environments for the South China Sea conflict scenario.

Insights on Forces and Capabilities

The final section of this chapter summarizes insights on forces and capabilities requested by the wargame air planning teams to support their concepts for counterair operations for both future great power conflict scenarios. Insights on air refueling, airborne BMC2 aircraft, and other capabilities needed to support these operations are addressed in Chapter 6.

Summary of Combat, ISR, and BMC2 Aircraft for Future Counterair Operations

Table 18 lists aircraft requested by the Indo-Pacific and European wargame planning teams to support their initial counterair operations.

TABLE 18: PMAI COMBAT, ISR, AND BMC2 AIRCRAFT REQUESTED BY TEAMS TO SUPPORT INITIAL COUNTERAIR OPERATIONS

Total PMAI In Theater Needed Adjusted for Mission Capable Rates				
Aircraft	**Europe Conflict Scenario**	**Indo-Pacific Conflict Scenario**	**Total PMAI**	**Notes**
F-16	40	120	160	
F-22A*	137	30	167	
F-35A	120	193	313	For counterair only, F-35As used for strikes (see Chapter 5) are additive
PCA/P-EA*	115	85	200	Future multi-mission capability
P-ISR*	38	78	116	Future UAS; includes the RQ-X played by teams
Multi-Mission UAS	29	155	184	Future multi-mission capability
RQ-4	0	15	15	
ABMS*	6	10	16	ABMS is a future family of systems, not a single aircraft
*** Denotes aircraft that support counterair (Chapter 4) and strike (Chapter 5) operations**				

Both the European and Indo-Pacific wargame planning teams were allowed to request PMAI aircraft up to the number that could feasibly be in the Air Force's operational inventory in the 2035–2040 timeframe. These force structure requests were then added to determine potential aircraft inventory demand for the two great power conflict scenarios assuming they occurred nearly simultaneously.[210] The number of PMAI aircraft in the total column in Table 18 were increased to account for an assumed average aircraft mission capable rate of 80 percent.[211]

210 As described in Chapter 3, "near simultaneous," for the purposes of this assessment, was assumed to be five to ten days between the start of hostilities for the first conflict and the start of hostilities for the second conflict.

211 Table 18 uses a standard mission capable rate of 80 percent, which is consistent with guidance from the Secretary of Defense to maintain F-35, F-22, F-16, and F/A-18 fighters at this rate. Actual mission capable rates in 2035 may be higher or lower for different aircraft.

Major Insights

The following insights on future counterair operations and capabilities developed during this study informed recommendations for the Air Force's aircraft inventory:

- Air superiority will be essential to achieving decision superiority and conducting offensive multi-domain operations at a tempo and scale needed to defeat future great power aggression;
- Airbases used by U.S. air forces during future great power conflicts in Europe and the Indo-Pacific will require layered defenses against air and missile threats;
- U.S. air forces will need to achieve a sufficient degree of temporary and localized air superiority to interdict enemy land, sea, and counterspace forces and provide close air support to friendly forces operating under an adversary's area-denial umbrella at the onset of hostilities;
- The Air Force's current counterair force structure lacks the capacity, survivability, and lethality to operate in future contested environments;
- There is a need for a future family of capabilities that can conduct offensive counterair operations over long ranges and into contested and highly contested environments; and
- Operations to attack enemy ballistic missiles prior to launch and intercept them in their boost phase will require a degree of air superiority.

Control of the air will be crucial to future multi-domain operations. Achieving air superiority in future high-end great power conflicts would increase the effectiveness of joint multi-domain operations and reduce the risk of enemy air and missile attacks on friendly forces. Chinese and Russia area-denial threats will challenge the U.S. military's ability to gain timely information on the disposition of enemy threats and forces located deep in contested and highly contested environments. Future U.S. counterair operations could help counter these threats and create the conditions that allow U.S. ISR assets from all domains to penetrate, persist, and gain the information needed to support joint operations. A resulting common operational picture would enable U.S. battle managers to make force employment decisions faster than opposing forces, which is critical to conducting successful information-ized warfare against China and Russia. The air domain is also an ideal arena from which to control and exploit the electromagnetic spectrum and conduct attacks through cyberspace. Furthermore, controlling the air domain would help enable airborne operations against an adversary's counterspace capabilities.

There is a need for layered airbase defenses. Wargame teams for both great power conflict scenarios proposed concepts to defend the Air Force's theater airbases against Russian and Chinese air and missile attacks. Without layered airborne and ground-based defenses, enemy missile salvos could greatly degrade the Air Force's ability to generate combat and other sorties during high-end conflicts with Russia or China. Maturing technologies including

directed energy weapons, lower-cost surface-to-air interceptors, and extended-range air-launched interceptors could help the U.S. military field a future airbase defense architecture with a significantly greater threat engagement capacity compared to current defenses that rely on a small number of expensive interceptors.

Future counterair weapon systems should also be capable of targeting ballistic missiles prior to launch and during their boost phase of flight. This would provide a more robust defense-in-depth against ballistic missiles compared to today's missile defense architecture. A future PCA /P-EA could be part of an integrated air and space sensor network to detect and track ballistic missiles. Given an increased weapons bay capacity compared to current-generation U.S. fighters, a PCA/P-EA could carry and launch extended-range missiles with sufficient kinematics to enable boost phase ballistic missile intercepts.

Counterair concepts and capabilities are needed to enable "day 1" joint operations. It is highly likely that U.S. and allied forces will need to conduct operations at the start of a great power conflict in areas that are covered by enemy area-denial capabilities. Operating concepts to sequentially roll-back these threats and then conduct close air support (CAS) and other missions would create opportunities for Russian and Chinese forces to exploit their control of the air to achieve their campaign objectives. The future U.S. counterair force should be capable of creating the degree of temporary and localized air superiority required to enable other U.S. air forces and weapons to interdict enemy threats and provide CAS to friendly forces at the start of a conflict.

The Air Force's counterair force structure is inadequate for future great power conflict. Much of the Air Force's current counterair force structure consists of platforms that are decades old and are best suited for operations in permissive environments. The force also lacks capacity to support a single great power conflict, much less this report's proposed force planning construct. Simply increasing the size (capacity) of the force will not suffice. The right mix of manned, unmanned, penetrating, and standoff capabilities and in sufficient capacity to conduct operations in the high end of the operational threat spectrum is also necessary.

A family of capabilities is needed for counterair operations in highly contested areas. A future air superiority family of capabilities, including a multi-mission PCA/P-EA and other capabilities to support multi-domain counterair operations, will need increased range, lethality, and the ability to operate in contested and highly contested environments in order to deliver timely effects. U.S. air forces currently lack these capabilities at a scale needed to target the full range of emerging air threats.

- **Range and payload.** Future air superiority aircraft should have increased payload capacity and an unrefueled combat radius that will allow them to operate from airbases located in lower-threat areas and then penetrate and persist in highly contested areas to support other U.S. air, land, and sea forces. Increased range and payload, and in turn persistence, would improve their ability to independently reach targets located deep in contested areas, would require less fuel from air refueling tankers, and could remain in

the battlespace for longer periods of time.[212] In this sense, increased range and payload would act as a force multiplier, requiring less force structure to meet the same operational requirements.

- **Survivability.** Future counterair systems should have signature control, kinetic and non-kinetic self-defense capabilities, and other characteristics that reduce the probability that enemy defenses will be able to complete the kill chain against them. A future PCA/P-EA will need sufficient speed to maneuver in the battlespace and defend protected assets against enemy air threats.
- **Lethality.** Future air superiority aircraft should have multi-spectral, multi-phenomenology sensor suites to support an organic capability to detect, track, and target threats in degraded communication environments. They should also have the capacity to carry large payloads of advanced weapons that are effective in highly contested environments, and sufficient space, power, and cooling capacity to allow for the integration of future weapons as they mature, including air-launched hypersonic and counter-ballistic missile weapons.
- **Battlespace awareness.** Future air superiority platforms will require organic sensing systems and the ability to share and receive information with other aircraft and weapon systems, both inside and outside of the highly contested environment.

Insights on Manned-Unmanned Teaming and Using Standoff Platforms for Air-to-Air Engagements

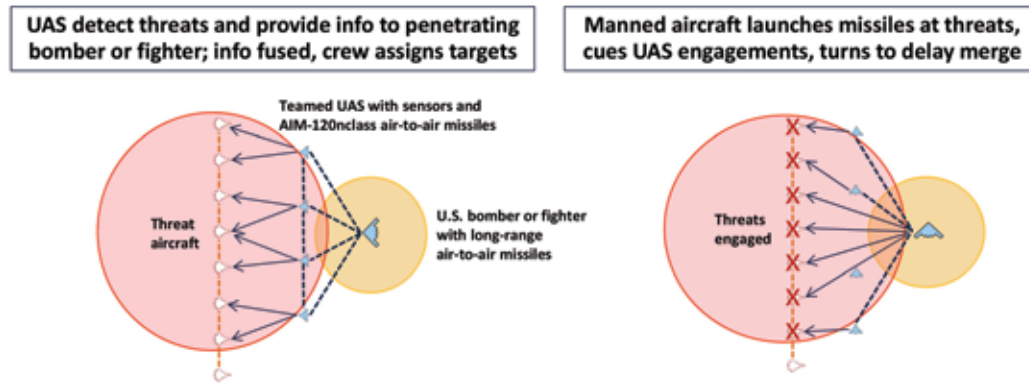
CSBA workshop and wargame teams also considered alternative approaches and capabilities that could support counterair operations in highly contested regions, including using manned-unmanned teaming approaches and a concept that used non-penetrating large aircraft such as bombers to engage air targets from standoff ranges using very-long-range air-to-air missiles (VLRAAM).

Manned-unmanned teaming. The Air Force is considering various permutations of teaming manned and unmanned aircraft to conduct counterair operations. Figure 31 shows a notional example of a penetrating bomber controlling UAS that act as distributed sensors

212 Aircraft range is related to mission persistence. Range is a function of three aircraft design variables: its ratio of lift to drag (L/D); its fuel fraction, which is defined as the ratio of an aircraft's total weight with fuel and total weight without fuel; and its engine fuel efficiency measured as specific fuel consumption (SFC). E. M. Greitzer, Z. S. Spakovszky, and I. A. Waitz, "16. Unified: Thermodynamics and Propulsion," lecture notes, version 6.2, 2007, "13.3 Aircraft Range: the Breguet Range Equation," available at http://web.mit.edu/16.unified/www/FALL/thermodynamics/notes/node98.html. The first two variables are important design tradeoffs, however, improvements to both may be constrained due to design or operational reasons. Future aircraft fuel efficiency could be significantly improved by developing combat rated engines with new propulsion technologies. New, more fuel-efficient engines could increase aircraft range by an estimated 30 percent, decrease tanker requirements, and may reduce O&S costs by reducing fuel requirements during training and other operations. Guy Norris, "GE Details Sixth-Generation Adaptive Fighter Engine Plan," *Aviation Week,* January 29, 2015, available at http://aviationweek.com/defense/ge-details-sixth-generation-adaptive-fighter-engine-plan.

and weapons launch platforms. Other approaches could team UAS with the F-35A or F-22 for counterair and other operations.

FIGURE 31: PENETRATING MANNED UNMANNED TEAMING CONCEPT ILLUSTRATION



While technologically feasible, there are cost and operational concerns with using this concept on a large scale in contested and highly contested environments.

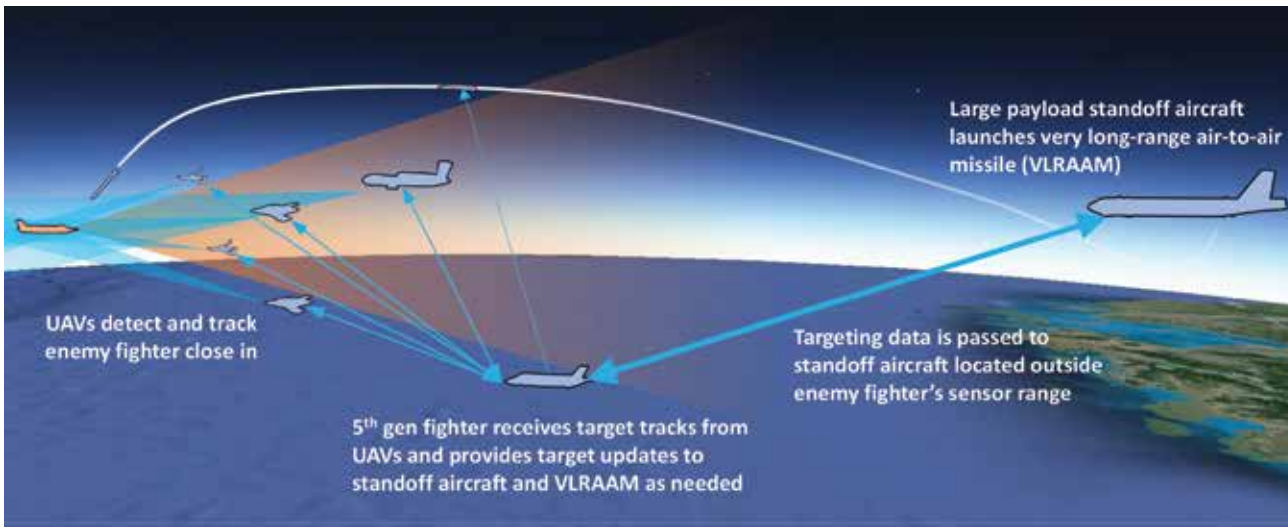
From a cost perspective, the UAS needed to support this concept during operations in the Indo- Pacific region and into highly contested environments would not be inexpensive. In this case, UAS would need to have ranges as long or longer than the manned penetrating aircraft they accompany and carry enough weapons to be useful. These fuel and weapons payload requirements would increase their size and unit cost. They would also need to be survivable, which could require them to have an expensive defensive suite of systems. In addition, the UAS would need to be equipped with advanced sensors and line-of-sight and possibly beyond line-of- sight communications needed to complete the air-to-air kill chain—design features that would further increase their cost.

From an operational perspective, it could be a challenge to maintain secure communications between teamed aircraft in highly contested areas where enemy forces have the capability to degrade and locally deny communications. Moreover, using manned penetrating platforms such as the B-21 as a "mothership" for teamed counterair operations may not be the best use of the bomber. During the initial stages of a high-intensity conflict with China or Russia, the B-21's ability to penetrate highly contested environments and carry large weapon payloads could be better used to attack enemy airfields and ground-based IADS rather than individual airborne threats. The use of manned-unmanned teaming concepts would be more practical from an operational viewpoint, however, as operating environments become more permissive. This would allow for the use of smaller and less-costly UAS, and it would improve communications and sensor operations. It may be possible to adapt current-generation UAS for manned-unmanned teaming counterair operations in permissive environments.

An offshoot of the concept in Figure 31 would be to pair a UAS with a 5th generation fighter. While this concept is technically achievable, the combat radius of the F-22 and F-35A and their limited ability to maneuver freely in future highly contested environments could constrain access and freedom of action for their paired UAS. Pairing UAS with a future PCA/P-EA could eliminate these limitations. However, these UAS would likely need to have survivability and range attributes similar to the PCA/P-EA that would increase their unit costs. For these reasons, manned-unmanned teaming may be a less valid concept for future air-to-air and SEAD missions over long ranges and into highly contested environments compared to using PCA/P-EA aircraft.

Standoff aircraft with long-range air-to-air missiles. Wargame planning teams considered concepts that employed standoff weapon platforms to launch long-range air-to-air missiles against airborne threats. As illustrated in Figure 32, manned or unmanned aircraft equipped with sensors and low probability of intercept/low probability of detection LPI/LPD datalinks could provide cues to shooter aircraft to complete the long-range engagement kill-chain.

FIGURE 32: CONCEPT TO COMBINE PENETRATING AND LARGE STANDOFF WEAPONS PLATFORM FOR AIR-TO-AIR ENGAGEMENTS



There are a number of operational concerns with this concept. In order to engage air threats, the threats must first be detected, tracked, and identified.

Detecting air threats is difficult for platforms that must standoff hundreds of miles from enemy air and surface threats. This difficulty is the product of factors such as the increased amount of sensor radiated power required to detect air threats over long ranges, sensor line-of-sight range limitations posed by terrain or the curvature of the earth, and meteorological challenges. These range limitations can be offset by using sensors that are located closer to

potential air targets—on land, at sea, in space, and on other aircraft—to detect, track, and identify targets, then pass target information to more remote platforms. However, transmitting target information over long ranges to cue launches from standoff platforms and then provide updated target information to their weapons while in flight would require assured and secure communications links. In highly contested environments, jamming, deception, and other enemy actions could degrade the effectiveness of these sensors and communications links.

Tracking aircraft over long ranges is also challenging. Targeted airborne aircraft are moving, not static, and must be tracked nearly continuously during an engagement. Aircraft maneuvering to avoid attacks combined with the use of decoys and electronic spoofing can cause tracking errors that would cause an air-to-air missile to "chase" intermittent target returns, some of which may be false. This would shorten the range of the missile or result in a missed intercept. Tracking errors such as these tend to be more pronounced during lengthy and distant air-to-air engagements. After being detected and tracked, targets must also be identified. Electronically identifying targets beyond visual range is challenging, and when extended-range identification is uncertain or cannot be achieved, effective missile engagements are unlikely.

FIGURE 33: ILLUSTRATING LIMITATIONS OF STANDOFF AIR-TO-AIR WEAPONS EMPLOYMENT

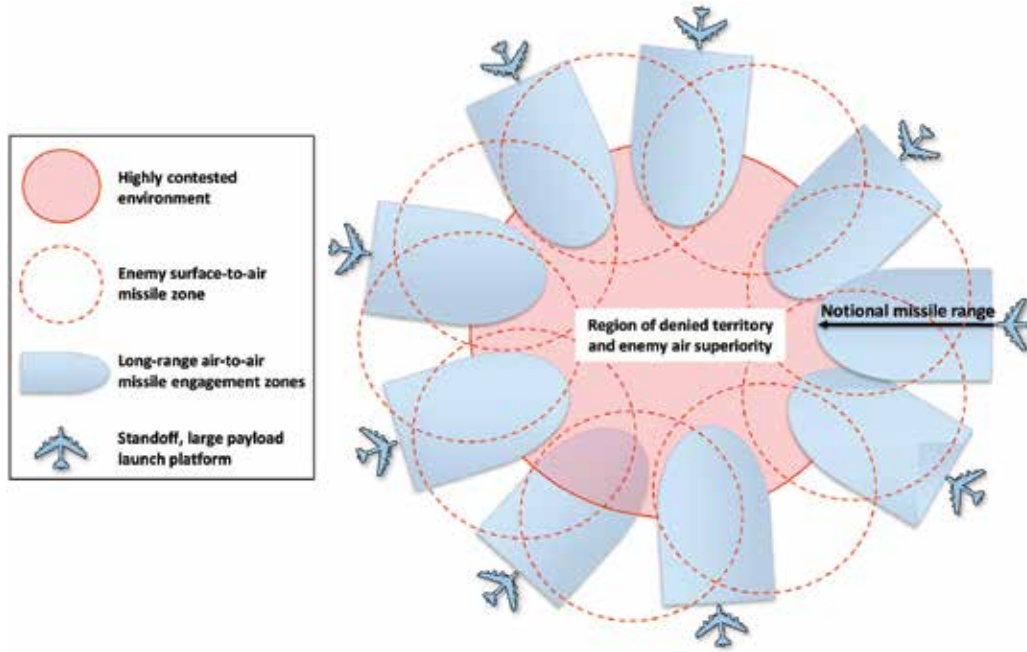


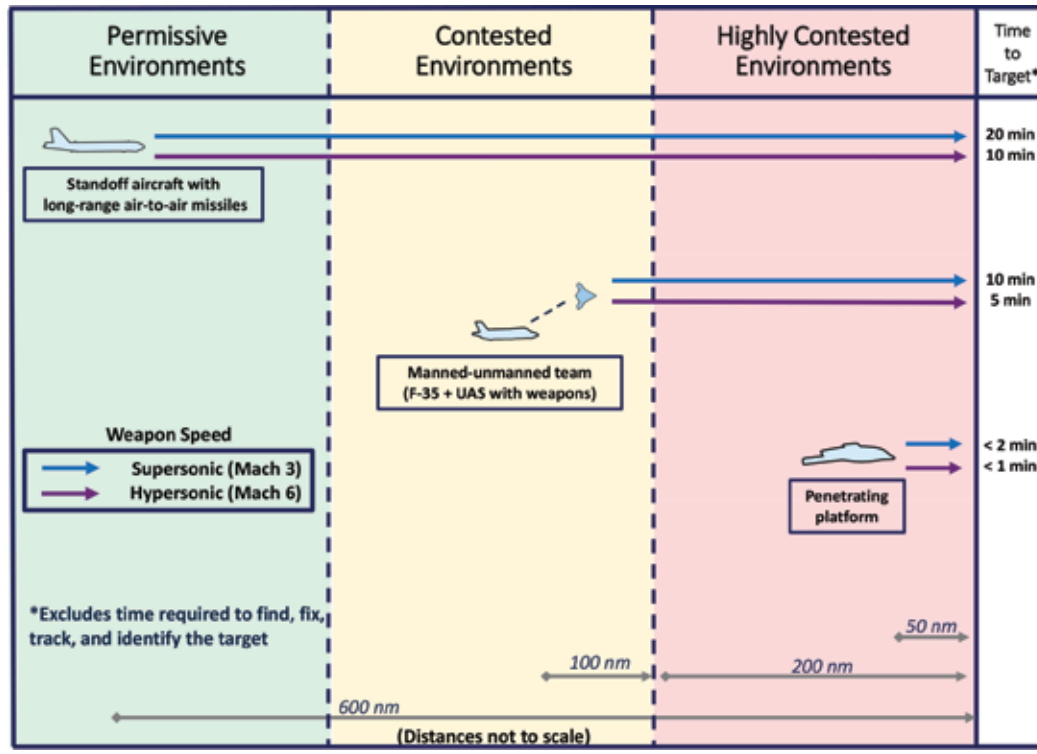
Figure 33 depicts an additional operational challenge. Due to Chinese or Russian threats, large, non-penetrating aircraft will likely have to remain hundreds of miles from the leading edge of a highly contested environment. Each of the blue "missile engagement zones" depicted in Figure 33 illustrates the area a standoff platform could cover if it has a payload of air-to-air missiles with a notional range of 600 nm. These blue areas are optimistic, since 600 nm maximum-range intercepts would only be feasible if the target aircraft was pointed directly at the air-to-air missile and did not change its heading for the duration of the engagement. In other words, an initial flanking profile or any maneuvering by the target aircraft, including slight heading changes, would require the air-to-air missile to maneuver, which would reduce its maximum range.[213]

Figure 33 also shows that it may take a significant number of standoff counterair aircraft to cover an objective area. In benign environments, it is technically possible to successfully demonstrate a small number of scripted long-range air-to-air missile engagements. However, scaling this concept to manage and protect friendly forces in major combat operations where hundreds of U.S. aircraft are reacting to dynamic threats in degraded communications environments would be far more challenging. Furthermore, attacking air targets over very long ranges takes time. On top of the time needed to identify, track, and pass target information to a standoff shooter, an air-to-air missile flying at Mach 3.0 (the typical speed of a contemporary air-to-air missile) could take multiple minutes to reach a distant target. Even a future hypersonic missile flying at Mach 6.0 could take ten minutes to reach a target located 600 nm from its launch aircraft (see Figure 34). This is likely too long for most air-to-air applications.

One last operational consideration should help inform the development of future concepts for using standoff platforms for counterair missions. During CSBA's workshops and wargames, demand for standoff bombers to conduct air-to-surface strikes against IADS, fixed military installations, and other targets exceeded the number of B-52H aircraft in the Air Force's real-world inventory. Allocating some number of these bombers to engage air-to-air threats would increase this capacity gap.

213 For a statistical assessment of this issue, see Venkatraman Renganathan, "Kill Zone Analysis for a Bank-to-Turn Missile-Target Engagement," Arizona State University, August 2016, available at https://repository.asu.edu/attachments/175032/content/Renganathan_asu_0010N_16277.pdf.

FIGURE 34: MINIMUM AIR-TO-AIR ENGAGEMENT TIMES AS A FUNCTION OF MISSILE SPEED AND STANDOFF DISTANCES



Summary

Air superiority enables joint military operations in all domains, including in space and cyberspace. Past DoD plans and investments assumed it would have the advantage of air superiority in conflicts. This is no longer a valid assumption. To address its growing shortfalls in counterair capabilities and capacity, the Air Force should trade mid- and low-end counterair forces for a modest amount of capability in the high-end of the operational spectrum. New capabili- ties should include systems for left-of-launch intercept of ballistic missiles, intercept of ballistic missiles in their boost phase, and layered air and missile defenses for U.S. forces and bases. The Air Force also needs new capabilities to conduct offensive counterair operations such as sweeps, escorts, SEAD, and strikes in order to enable offensive multi-domain operations at a tempo and scale necessary to defeat great power aggression. Future counterair weapons systems, including a multi-mission capable PCA/P-EA aircraft, should be able to operate over long ranges and in highly contested environments, carry a large number of direct attack and standoff munitions, and have a sensor suite that provides a fused, multi-domain operational picture of the battlespace.

Considering the Air Force's lack of counterair capacity for high-intensity conflicts and the limited remaining service life on its inventory of F-15C/D fighters, development of a new generation of counterair capabilities should be a high priority. A 15- to 20-year program

similar to the F-22 and F-35 programs to develop new weapons systems such as a PCA/P-EA would create a significant gap in the Air Force's counterair capabilities. Reducing the acquisition timeline will require DoD and the Congress to commit to stable funding and a combination of alternative acquisition approaches recommended by the Defense Science Board, Government Accountability Office, and others.[214] This approach could include increased competition and leveraging consumer-off-the-shelf products to take advantage of technology cycle times.

In summary, China and Russia are now capable of using their multi-domain area-denial capabilities to provide sanctuary to their anti-access weapons and offensive operations. The U.S. DoD has failed to keep pace with these emerging threats. Today's counterair force structure is weighted entirely in the middle and low end of the operational spectrum. As a result, much of the Air Force's current counterair force would have to operate with a high degree of risk in a high-intensity conflict with a great power. Ceding air superiority in the high end of a denied region during a conflict would erode the U.S. military's ability to conduct offensive and defensive operations against a great power. To sustain its advantage in the air, the Air Force should shift its counterair force structure from capabilities that are best suited for wars of the past toward a future force mix that has the capability and capacity to conduct operations in the high end of the operational spectrum.

214 Defense Science Board, *Design and Acquisition of Software for Defense Systems* (Washington, DC: DoD, February 2018), available at https://www.acq.osd.mil/dsb/reports/2010s/DSB_SWA_Report_FINALdelivered2-21-2018.pdf; and Government Accountability Office (GAO), *Weapon System Requirements: Detailed Systems Engineering Prior to Product Development Positions Programs for Success* (Washington, DC: GAO, November 2016), available at https://www.gao.gov/assets/690/681106.pdf.

CHAPTER 5

Concepts and Capabilities for Future Air Force Global Strike

The U.S. military has long been accustomed to having an unmatched dominance in precision strike. The ability to attack over long ranges with precision has been part of the foundation of U.S. post-Cold War operating concepts designed to halt quickly and then roll back regional militaries invading an ally or partner state. The proliferation of precision guidance technologies, cruise and ballistic missiles, and other modern weapons has eroded this overmatch. Russia, China, and to a lesser extent Iran and North Korea, have large inventories of guided weapons that are capable of threatening U.S. forces and bases located in their regions. The "precision revolution" has also advantaged defenses against U.S. air and missile attacks. Russian and Chinese A2/AD complexes include IADS that are increasingly capable of defending against U.S. cruise missiles and other PGMs as well as the platforms that launch them. Given the continuing maturation of Russia's and China's offensive and defensive A2/AD capabilities, precision strike salvo competitions should be considered a part of the larger competition between great powers.

DoD has used the term "salvo competition" to describe the dynamic between militaries that continuously seek to gain new advantages by improving their capabilities to attack with precision and defend against competitors' precision strikes. Previous CSBA reports have assessed the implications of salvo competitions between the U.S. military and Russian and Chinese forces.[215] One insight is that attempting to use more mass (additional strike aircraft and munitions) to compensate for attrition caused by precision-enabled air and missile defenses is not feasible for campaigns against very large target sets. Another insight is that current-generation PGMs designed for use in permissive environments could have low probabilities of reaching

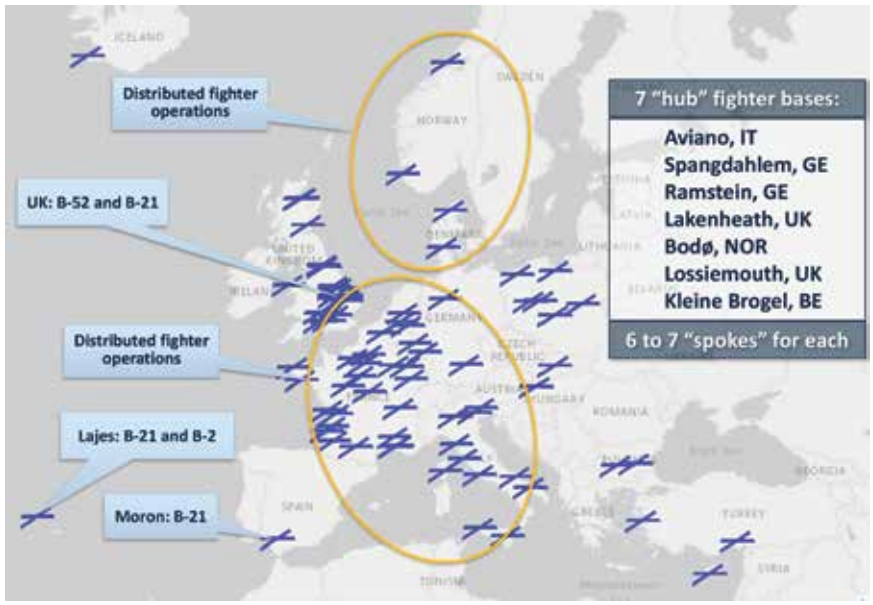
215 See, for instance, Mark Gunzinger and Bryan Clark, *Sustaining America's Precision Strike Advantage* (Washington, DC: Center for Strategic and Budgetary Assessments, 2015); and Mark Gunzinger and Bryan Clark, *Winning the Salvo Competition: Rebalancing America's Air and Missile Defenses* (Washington, DC: Center for Strategic and Budgetary Assessments, 2016).

targets in contested and highly contested environments. Furthermore, the overwhelming majority of air-to-surface munitions procured by DoD over the last two decades have been unpowered, direct attack gravity weapons that have short ranges (less than 50 nm). The use of short-range, direct attack munitions such as the Joint Direct Attack Munition (JDAM) require strike aircraft to engage targets at short distances, which could place the aircraft within the most lethal range of Russian or Chinese air defenses.

Assessments of the Air Force's future force structure requirements should consider new operating concepts and a mix of capabilities that may be needed to overcome these challenges; this would include munitions, sensors, and C2 networks as well as strike aircraft. Chapter 5 summarizes insights on potential strike concepts and capabilities that were developed by teams of experts acting as air planning teams during workshops and a wargame based on the illustrative scenarios described in Chapter 3.

Insights on Strike Operations: Future Baltic Sea Region Conflict Scenario

FIGURE 35: INITIAL POSTURE FOR STRIKE AIRCRAFT IN EUROPE

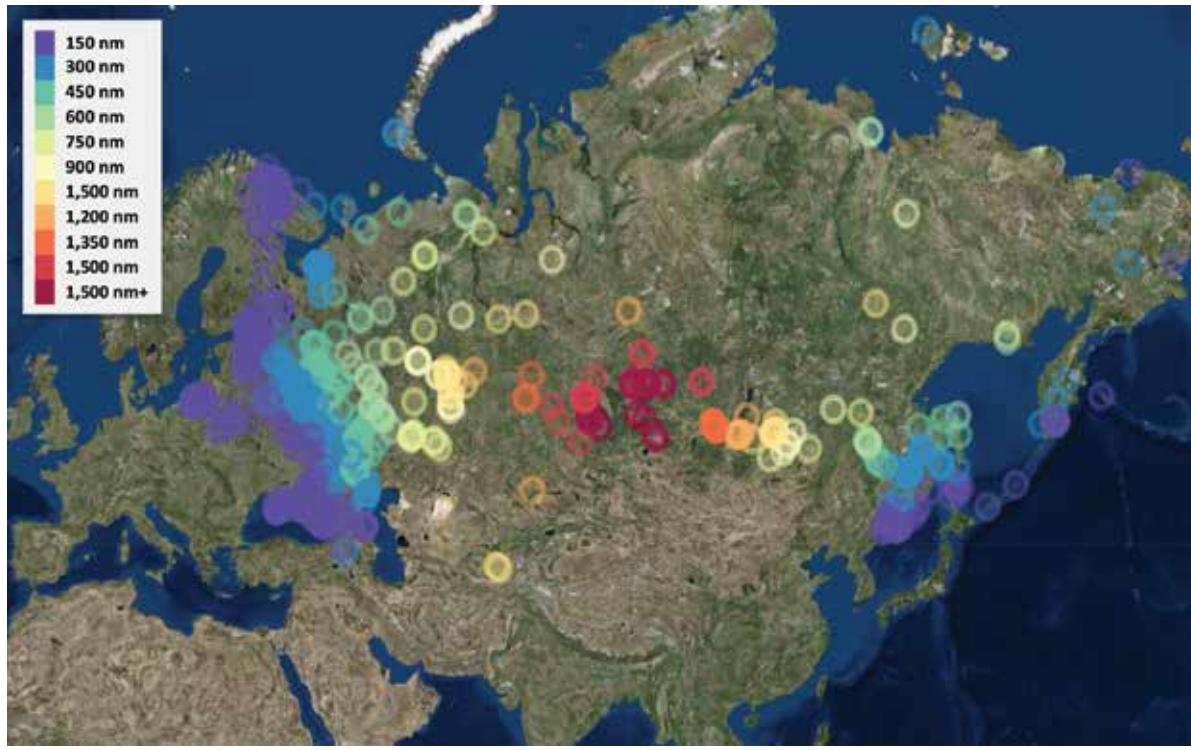


Basing Assumptions and a Notional Target Set for U.S. Strike Operations

Basing and access assumptions. A wargame air planning team challenged with the Baltic Sea scenario described in Chapter 3 assumed that Russia could target airbases hosting U.S. and NATO 5th generation fighters, bombers, tankers, and other high-value aircraft. To reduce the risk of attack, the wargame team dispersed their fighter forces at airfields located across Western Europe and postured its bombers, tankers, and other large aircraft at even greater distances from Russian surface-to-surface fires (see Figure 35).

Notional target set. To support the European wargame, CSBA developed of a notional Russian target set to support analysis of the Baltic Sea region conflict scenario. The target set has over 29,000 aimpoints for hardened or deeply buried military facilities, mobile or relocatable missile launchers, long-range artillery, mechanized forces, Russian fighter and bomber bases, and other targets (see Figure 36).[216] These aimpoints were derived from unclassified sources, are limited to potential conventional counter-force targets, and do not include all possible targets that may be of interest to future U.S. and NATO campaign planners.[217]

FIGURE 36: DEPTH AND CONCENTRATION OF A NOTIONAL RUSSIAN TARGET SET



The European air planning team used this target set to define objectives for their initial airstrikes against Russia, including its IADS, C2 nodes, fielded forces engaged in offensive operations against NATO, lines of communication, and other targets. These objectives shaped the team's operating concepts for strike, SEAD/DEAD, close air support, and the force structure needed to support their air campaign.

216 About 42 percent of the target set's aimpoints are located west of Moscow. This was by intention, since the target set was designed to support wargames oriented on a NATO conflict with Russia in the Baltic Sea region. DoD defines the term "aimpoint" as "A point associated with a target and assigned for a specific weapon impact." See CJCS, *DoD Dictionary of Military and Associated Terms*, p. 8. This report uses the term "aimpoint" instead of "target," since a target may have multiple aimpoints that should be attacked to achieve a desired degree of destruction.

217 The target set does not include potential targets for counter-value strikes.

Team Concepts and Priorities for Strike and Close Air Support Operations

Maximize simultaneity. Given Russia's time and distance advantages in a future Baltic Sea region scenario, the team determined the highest priorities for its initial air campaign operations should be halting and then destroying invading Russian ground forces, suppressing A2/AD threats covering the joint operating area, and providing close air support to friendly forces *simultaneously*. Attempting to sequentially roll-back Russian IADS in the region before attacking its invading forces would create a window in time for Russia to close a land bridge between Belarus and Kaliningrad and cut NATO's ground lines of communication to the Baltic states, thereby achieving its assumed military objectives.

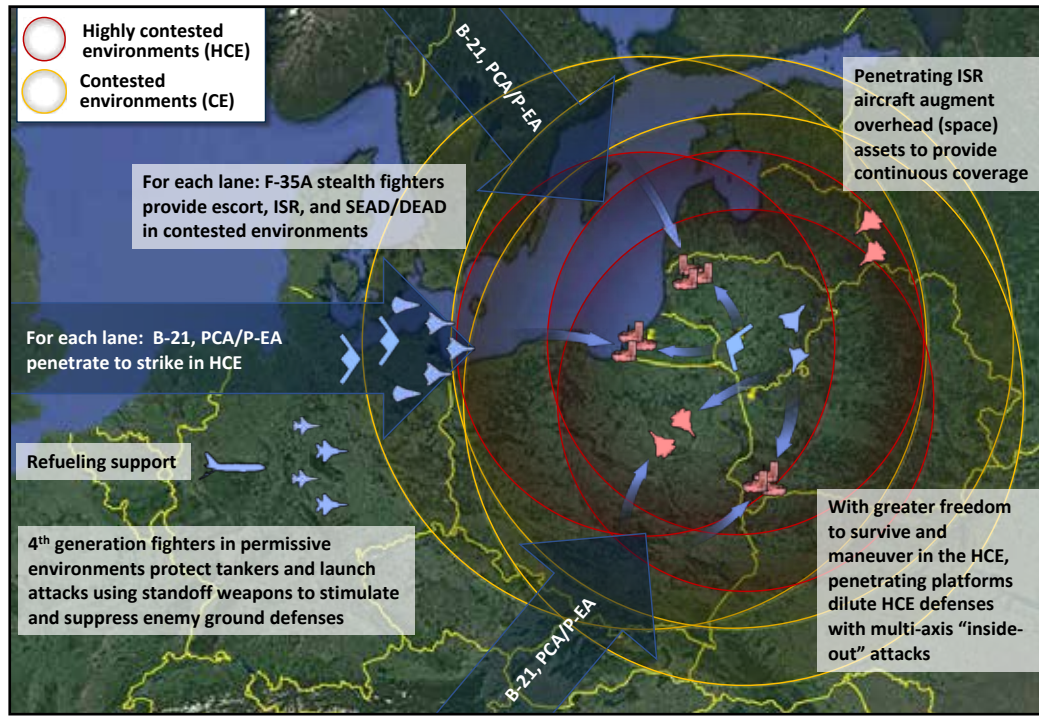
Prioritize the interdiction of Russian offensive ground forces and lines of communication. The team's overarching objective was to halt Russia's advance into Lithuania within the first seven days of the start of conflict. Over the first four days of conflict, U.S. multi-domain operations would include penetrating air strikes, standoff air strikes, fires from available NATO ground artillery and missile launchers, electronic warfare, and other actions to isolate and then attrite Russia's first echelon forces in Lithuania. These operations would be complemented by penetrating and standoff air attacks against nodes in Russia's road and rail lines of communication to halt its flow of troops and prevent their resupply.

Degrade and then defeat Russia's A2/AD umbrella. The team's CONOPS emphasized strikes against Russia's surveillance and acquisition radars and strategic SAMs to increase freedom of action for NATO aircraft in the joint operating area. Penetrating B-21 bombers and other combat aircraft would use target information provided by their onboard sensors, PCA, P-ISR, and overhead assets to attack Russian mobile SAMs and missile TELs. These penetrating strikes would be augmented by standoff weapons attacks launched by non-stealth U.S. fighters and bombers against Russian airbases and other fixed military targets located in Kaliningrad and Belarus.

Attack from multiple directions to create a complex challenge for Russia. To complicate Russia's ability to defend against U.S. air operations, the team planned to penetrate simultaneously from multiple axes and then attack from multiple directions once inside contested airspace. Figure 37 illustrates one operating concept for multi-aspect attacks to suppress and destroy Russian air defenses in Kaliningrad, Belarus, and deployed into Lithuania to defend Russian maneuver forces.

FIGURE 37: TEAM'S CONCEPT FOR MULTI-ASPECT INSIDE-OUT ATTACKS TO SUPPRESS ENEMY AIR DEFENSES IN HIGHLY CONTESTED ENVIRONMENTS

The concept would use F-35A fighters to conduct SEAD/DEAD strikes (primarily using SiAW)



and airborne electronic attacks to suppress threats in contested areas.[218] Decoys and standoff weapon attacks launched by non-penetrating 4th generation fighters, UAS, and available ground fires would help stimulate Russian defenses to radiate, relocate, or otherwise respond in ways that would increase their probability of detection by U.S. forces.[219]

As show in Figure 37, B-21 bombers, PCA/P-EA aircraft would penetrate highly contested environments from multiple axes.[220] Their attack lanes would not be linear or follow the same routes for each offensive pulse into contested airspace. Since it is unlikely that NATO forces could quickly suppress Russian IADS covering the joint operating area, multi-domain operations would help to create temporary and localized air superiority sufficient for

218 Swarming concepts for SEAD/DEAD were also considered. Due to the short ranges of small, swarming unmanned vehicles, their questionable survivability against electronic countermeasures and other defenses, challenges created by weather, and the "tax" they induce on force structure used to deliver them in necessary quantities, such strikes were thought to cost more than using relatively affordable, survivable unitary weapons such as the Joint Air-to-Surface Standoff Missile (JASSM) and SiAW for SEAD/DEAD.

219 Conducting integrated standoff and penetrating strikes would present Russia's air defenses with a multi-dimensional challenge.

220 Notional descriptions of these future stealth aircraft are provided in Appendix A.

penetrating aircraft and weapons to accomplish their missions. Overhead sensors and sensors on Penetrating-ISR (P-ISR), B-21, PCA/P-EA aircraft operating in the battlespace would detect, locate, track, and provide target information to be fused with data from other airborne and ground-based sensors to create an operational picture that will give U.S. and other NATO forces decision superiority.[221] The smaller blue arrows in Figure 37 illustrate the multi-axis attacks that would force Russia to defend in all directions and help reduce its ability to concentrate its area defenses. Diluting an enemy's defenses will help increase the survivability of NATO's attacking platforms and weapons.

Provide close air support to friendly ground forces on day 1 of the conflict. Should a conflict with Russia occur with little advance warning, it is likely that the United States and its NATO allies would not have sufficient time to deploy a large number of land-based fires units into the battlespace. This could increase the need for U.S. air forces to provide CAS and other fires to support friendly ground forces in contact with the enemy on day 1 of combat operations. In this event, the team planned to use B-21 bombers supported by PCA/P-EA to provide the preponderance of close air support in highly contested environments, and F-35A fighters augmented by some precision standoff attacks for CAS in contested environments. Due to the density and lethality of Russia's IADS, 4th generation and upgraded "4-plus" generation fighters would not be suitable for CAS or direct attacks on enemy ground forces located in contested areas.

Sustain continuous pressure. Strike, interdiction, counter-IADS, and CAS operations for this scenario should be continuous, not episodic. The wargame air planning team recommended that U.S. air forces deployed to Europe should have sufficient aircraft, munitions, and other required equipment to sustain up to eight mission pulses per day for each of the three attack lanes illustrated in Figure 37, to be augmented by standoff-strikes in between pulses. More infrequent pulses by a smaller deployed force would reduce pressure on Russian forces and give them more time to reconstitute and continue their offensive.

Other Operations

Maritime strikes. The wargame team planned air operations to interdict sea lines of communication to Kaliningrad, marginalize the operations of Russia's Baltic Fleet, and degrade the ability of Russian ships from its Northern Fleet to support the assault on NATO. Priority targets included military ports and naval fuel supplies in Kaliningrad and Russian Navy ships operating in the Baltic Sea, which would be engaged by U.S. B-52H bombers with F-35A fighters in support. B-21 bombers supported by PCA/P-EAs would use anti-ship cruise missiles similar to the Long-Range Anti-Ship Missile (LRASM) against Russia's Northern Fleet ships and future standoff air-launched mines to cut sea line of communication from St. Petersburg.

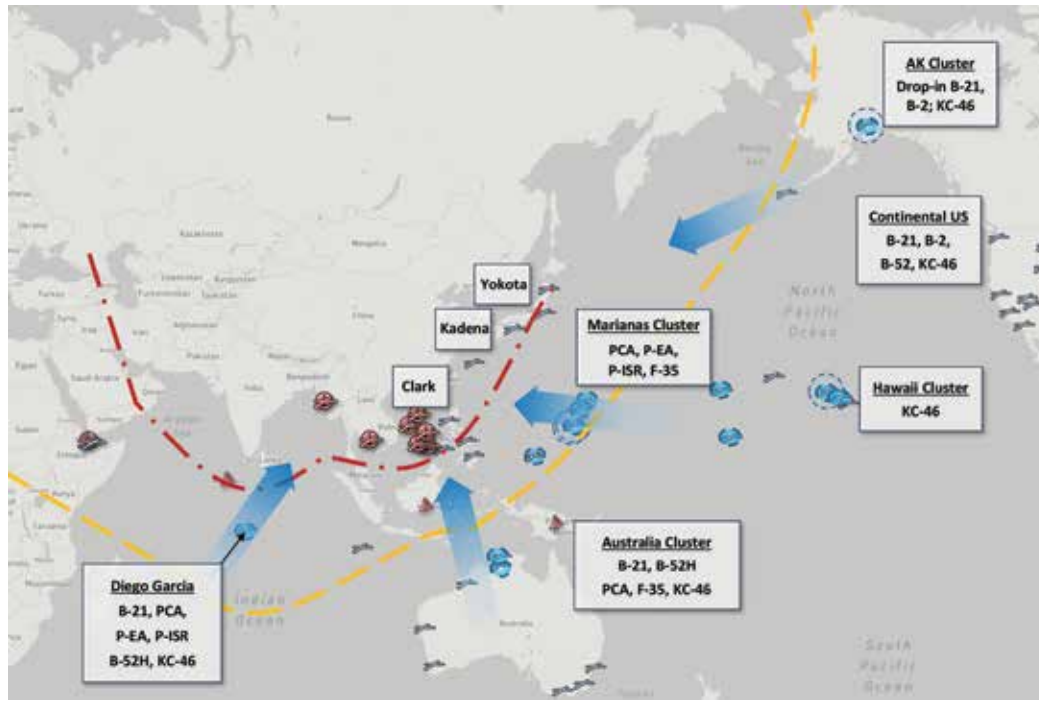
221 The persistent presence of penetrating unmanned ISR in the battlespace would help cover gaps in overhead sensor coverage created by attacks on U.S. and NATO space networks.

Air refueling and airborne BMC2 operations. The team planned to operate its tankers over France, western Germany, Austria, northern Italy, Hungary, and other areas that were located at least 500 nm from Russian strategic SAMs deployed in Kaliningrad. U.S. airborne surveillance platforms and other high-value aircraft would operate over western Germany and other locations sufficiently distant from Kaliningrad to reduce the risk of attack from Russian long-range air defenses. These standoff distances would reduce their ability to form an accurate picture of the battlespace and manage highly dynamic U.S. air operations. U.S. fighter CAPs would counter Russian long-range interceptors attempting to attack NATO tankers and other supporting aircraft that lack defenses and cannot quickly maneuver to avoid threats.

Insights on Strike Operations: Future South China Sea Conflict Scenario

Basing Assumptions and a Notional Target Set for U.S. Strike Operations

FIGURE 38: INITIAL POSTURE FOR STRIKE AIRCRAFT IN THE PACIFIC

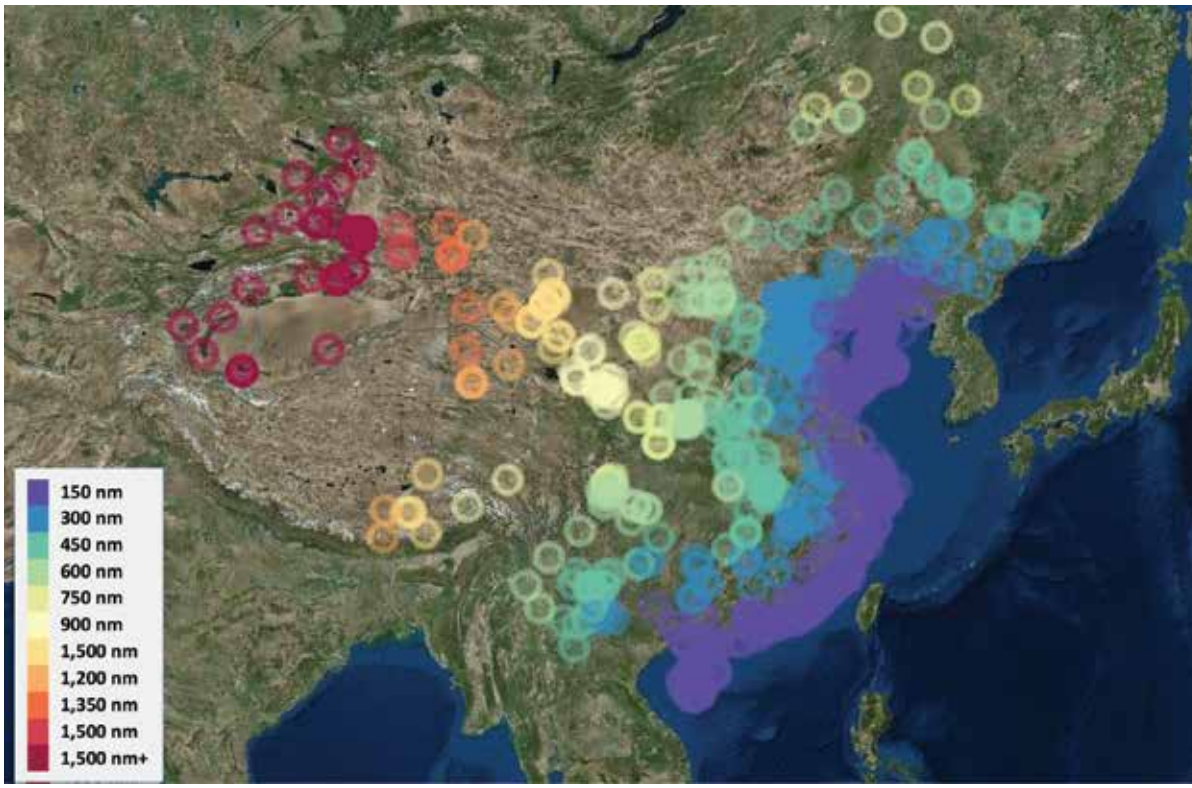


Basing and access assumptions. The Indo-Pacific wargame planning team postured its initial strike forces at airfields in the Mariana Islands, northern Australia, Diego Garcia, and in the Continental United States. These strike forces complemented fighters and other aircraft distributed throughout the region. Figure 38 depicts the team's initial basing posture, which included bombers and tankers operating from the United States to support early strikes.

Notional target set. Similar to the European scenario, a notional target set was used by the Indo-Pacific wargame planning team. The target set included approximately 2,100 aimpoints

for buried or hardened Chinese military facilities, 6,500 aimpoints for mobile or relocatable weapon systems, 11,000 aimpoints for fighter and bomber airbases, and 14,000 aimpoints for facilities critical for sustaining China's offensive military operations. As illustrated by Figure 39, about 70 percent of the target set's 50,000 aimpoints are located within 250 nm of the coastline of mainland China, and 9 percent are located within 1,000 nm of the coast. The deepest aimpoints (red circles) indicate locations of known or suspected military space installations, anti-satellite weapons sites, and other potential high-value targets.

FIGURE 39: DEPTH AND CONCENTRATION OF A NOTIONAL CHINA TARGET SET

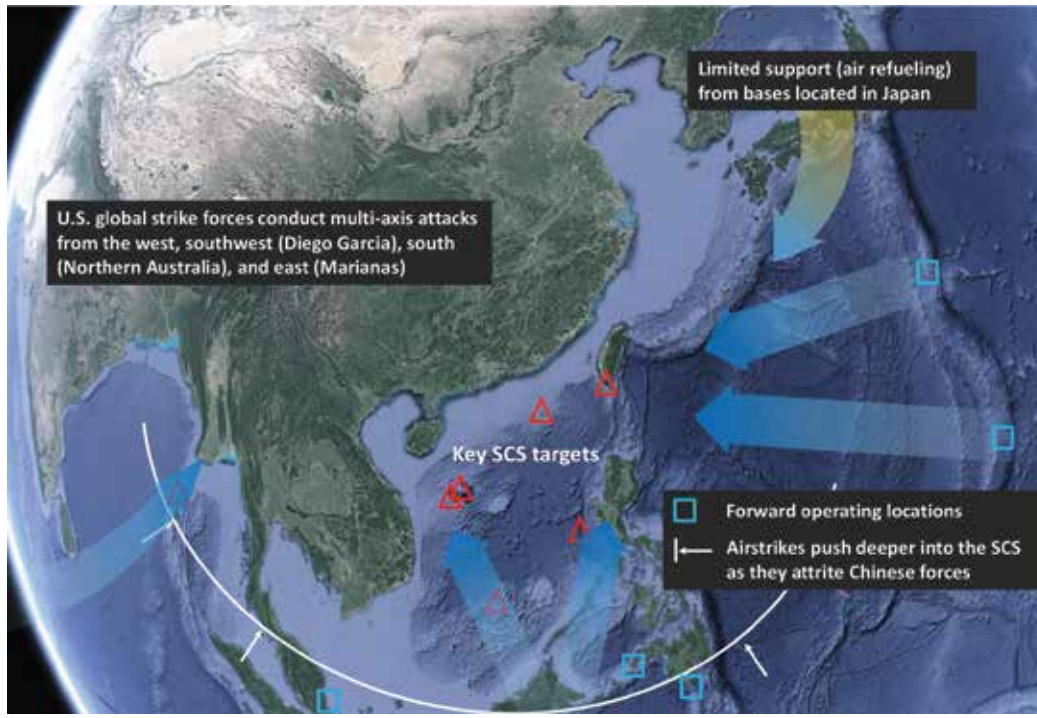


The wargame planning team used this target set to define objectives for their initial strikes against China, including its forces and military installations located in the South China Sea, C2 nodes, and other targets they deemed critical to the PLA's offensive operations.

Priorities and Operational Concept for Strikes during the First 36–72 Hours of Operations

Blind and then degrade China's long-range ISR and strike capabilities. The team's concept for offensive air operations prioritized reducing Chinese A2/AD threats located on the mainland and on occupied islands in the South China Sea. Since the ability to accurately find, fix, and track potential targets over long ranges is the Achilles' heel of an A2/AD complex, U.S. strikes would initially concentrate on the PLA's long-range early warning sensors and nodes in its command and control networks. Simultaneous strikes against PLA Air Force bomber airfields, other military air installations within 150 nm of its coastline, missile bases, and missile launch sites were intended to further reduce the frequency and capacity of China's salvo attacks on U.S. forces and bases.

FIGURE 40: OPERATING CONCEPT FOR INITIAL ATTACKS ON SCS TARGETS AND MAINLAND A2/AD THREATS



Conduct all-aspect attacks to degrade and suppress Chinese area denial threats. As illustrated by Figure 40, the team planned to launch airstrikes on military targets in mainland China and the South China Sea from multiple approaches. This operating concept employs long-range penetrating B-21 bombers, PCA and P-ISR aircraft, and non-stealth aircraft capable of launching survivable standoff attack weapons. Penetrating strikes over the first three days of the air campaign would focus on anti-satellite capabilities located deep in

China's interior, C2 nodes on the mainland and in the South China Sea, and PLA bomber and fighter command and control facilities.

Lines of attack into the South China Sea. As shown in Figure 40, long-range bombers flying from airfields in northern Australia and the Mariana Islands supported by F-35A and PCA/P-EA aircraft would suppress PLA SAMs, early warning assets, and C3 assets located in the South China Sea. Strikes into the SCS would progressively move from the south to the north and from the east to the west. These operations would be fully integrated with naval fires, electronic warfare, and cyberattacks to achieve maximum results and reduce threats to penetrating aircraft and their salvos of weapons.

Lines of attack against offshore and coastal targets. Penetrating bombers supported by PCA aircraft and stand-in electronic attack aircraft would target Chinese long-range early warning sensors and C2 nodes on the mainland to deny situational awareness to PLA forces operating in the SCS. Penetrating electronic attack aircraft would provide jamming support and stimulate Chinese air defense systems to activate their radars, which could then be detected by passive sensors on P-ISR or other aircraft.[222] Similar SEAD/DEAD aircraft cells could suppress Chinese SAMs and other air defense threats to help create a sufficient degree of temporary, localized air superiority needed to support penetrating strikes. Unmanned penetrating ISR would help locate, track, and cue bomber strikes against mobile and relocatable SAM systems.

Stealth bombers supported by PCA/P-EA aircraft to detect and suppress pop-up air defense threats would attack PLA airfields to degrade their ability to generate bomber and fighter sorties. The bombers would carry PGMs with capabilities suitable for strikes in contested environments, including sufficient standoff ranges to ensure bombers could strike targets with an acceptable degree of risk. Other penetrating cells supported by standoff weapons launched by F-35As and B-52Hs would target the PLA Navy's South Sea Fleet headquarters and C2 nodes located near Hainan Island.

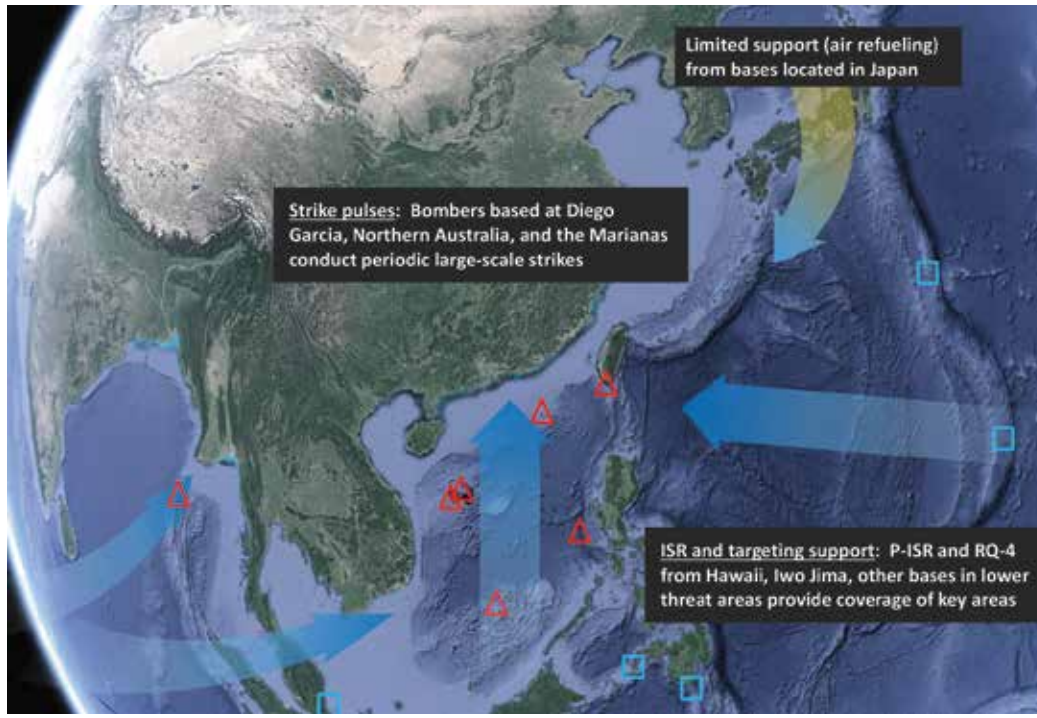
Lines of attack against deep targets. The wargame planning team allocated B-21 bombers, PCA/P-EA, and P-ISR aircraft to conduct deep penetrating strikes on elements of the PLA's space control network and ASAT forces. These strikes were planned to occur within the first three days of the air campaign in order to reduce China's ability to degrade U.S. and coalition space networks. The B-21s would employ survivable standoff strike weapons to reduce their depth of penetration into China and avoid air defenses that are likely deployed around high-value fixed military space targets. B-21s could also launch attacks on IADS located along the China's east coast. This would present the PLA with a multi-aspect threat that could dilute their ability to concentrate its defenses against U.S. aircraft.

222 Capability attributes of potential future P-ISR and P-EA aircraft are notional and are suggested here for the purpose of illustrating operating concepts for strike in contested environments.

Team Concept for Strikes Against Relocatable or Mobile Targets

The team planned to sustain a significant level of effort to degrade PLA offensive systems as well as Chinese A2/AD systems that threatened the freedom of action of U.S. forces operating in the South China Sea. Suppressing Chinese SAMs, missile TELs, and other A2/AD systems that are highly mobile would be extremely challenging. The team planned to pulse every 12 hours from different directions with B-21 bombers carrying survivable air-launched weapons to improve their ability to strike defended time-sensitive mobile/relocatable targets (see Figure 41). This sustained level of effort would require persistent ISR provided by space-based sensors and P-ISR aircraft to help complete the kill chain before potential targets relocate.

FIGURE 41: CONCEPT FOR SUSTAINED ATTACKS AGAINST TARGETS THAT REGENERATE OR ARE DIFFICULT TO LOCATE



Non-penetrating bombers carrying the Joint Air-to-Surface Standoff Missile–Extended Range (JASSM-ER) and long-range hypersonic weapons could supplement these penetrating strike operations, although the time of flight of very-long-range hypersonic weapons could reduce their effectiveness against targets such as advanced mobile SAM systems that can quickly reposition.

The team also allocated B-2s, B-21s, and F-35As to attack Chinese surface action groups operating in the South China Sea. Supporting the Navy with these maritime strikes was considered

a high priority, since U.S. aircraft carriers may not be able to operate close enough to the South China Sea early in the fight to launch attacks on all of their assigned targets.

Insights on Forces and Capabilities

The final section of this chapter summarizes insights on the forces and capabilities requested by the Indo-Pacific and European wargame air planning teams to support their concepts for strike, close air support, and SEAD/DEAD operations. Insights for air refueling, airborne BMC2, and other capabilities needed to support these operations are addressed in Chapter 6.

Total combat and ISR aircraft requested for the future great power conflict scenarios. Table 19 lists aircraft requested by wargame planning teams to support their operating concepts.

TABLE 19: PMAI COMBAT AIRCRAFT REQUESTED BY TEAMS TO SUPPORT STRIKE, SEAD/DEAD, AND CLOSE AIR SUPPORT OPERATIONS

Total PMAI Needed in Theater Adjusted for Mission Capable Rates			
Aircraft	**Europe Conflict Scenario**	**Indo-Pacific Conflict Scenario**	**Total PMAI**
B-2	15	0	15
B-21	86	106	192
B-52H	30	52	82
F-15E	100	0	100
F-22A*	137	30	167
F-35A	145	128	273
PCA/P-EA*	115	85	200
MQ-X	30	20	50
P-ISR*	38	78	116
* Denotes aircraft that support counterair (Chapter 4) and strike (Chapter 5) operations			

Both the teams were allowed to request PMAI aircraft up to the number that could feasibly be in the Air Force's operational inventory in the FY 2035-2040 timeframe. These requests were then added to determine potential aircraft inventory demand for the two future great power conflict scenarios assuming they occurred nearly simultaneously.[223] PMAI aircraft in the total column in Table 19 were increased to account for an assumed average aircraft mission capable rate of 80 percent.[224]

223 As described in Chapter 3, "nearly simultaneously" for the purposes of this assessment was assumed to be five to ten days between the start of hostilities for the first conflict and the start of hostilities for the second conflict.

224 Table 19 uses a standard mission capable rate of 80 percent, which is consistent with guidance from the Secretary of Defense to maintain F-35, F-22, F-16, and F/A-18 fighters at a mission capable rate of at least 80 percent. Actual mission capable rates in 2035 may be higher or lower for different aircraft.

Major Insights

The following insights on future strike, SEAD/DEAD, and CAS operations and capabilities informed this report's recommendations for the Air Force's aircraft inventory:

- There is a need to improve the Air Force's capabilities and increase its capacity to conduct ISR, strike, SEAD/DEAD, and CAS operations in contested and highly contested environments;
- The Air Force should shift from a platform-centric focus for these operations toward concepts for conducting distributed operations using a family of capabilities;
- Traditional "roll-back" (or outside-in only) approaches to suppress Russian and Chinese IADS will be costly and may take too much time;
- Successful targeting of most air-to-air and surface-to-air threats will require stand-in (penetrating) delivery platforms that can find, fix, track, target, and attack rapidly relocatable targets;
- A new delivery platform and effective kinetic weapons are needed for SEAD/DEAD operations in the highly contested environment;
- A balanced force of penetrating and stand-off ISR and strike forces will be needed to support high volume strikes against large target sets located in contested and highly contested areas;
- Penetrating UAS combined with ISR from overhead sensors could provide the persistent and resilient ISR needed in future battlespaces against target sets that are increasingly mobile/can quickly relocate;
- Survivable bombers with large payloads of lower-cost munitions should be the predominant capability used for air strikes over very long ranges and into highly contested environments for air campaigns against large target sets that last more than a few days;
- Non-penetrating bombers, 4th generation fighters, and UAS could be in high demand for conducting future standoff strikes and other operations. Keeping these aircraft in the active inventory would free penetrating systems for operations in contested and highly contested environments; and
- Combinations of future penetrating aircraft and weapons will need a greater ability to organically complete the strike kill chain in environments where C2ISR networks are more vulnerable and likely to be degraded.

These insights assume that there will be sufficient fuel, munitions, and other enabling capabilities to support the teams' operating concepts.

Increased capacity for combat operations in contested and highly contested environments. Although stealth platforms and weapons are not immune to attacks, low-observable technology will be the price of admission for U.S. air forces to operate effectively in contested environments. The teams requested a combined total of 207 PMAI B-21 and B-2 stealth bombers after factoring in an 80 percent mission capable rate to support their planned strike operations against Chinese and Russian forces. In the second quarter of FY 2019, the Air Force's inventory of stealth aircraft consisted of 16 PMAI B-2 bombers, 48 PMAI F-35A, and 123 PMAI F-22A fighters. The Air Force has announced that it intends to buy 100 B-21 bombers with initial deliveries beginning in the mid-2020s. Both teams planned to use significant numbers of F-35A and future PCA/P-EA and P-ISR aircraft in their air campaigns. F-16 and A-10 fighters were not used for strikes, SEAD/DEAD missions, or CAS since their ability to freely maneuver in the contested environment is severely restricted and their capacity to employ standoff weapons was inefficient for standoff strikes.[225]

Shift toward distributed operations using a family of capabilities. Operating concepts developed during the workshops and wargame used a family of capabilities to conduct strike, SEAD/DEAD, and CAS in contested and highly contested threat environments. These concepts reflect the need to assess how combinations of current-generation and future manned and unmanned aircraft, sensors, weapons, and other mission systems could achieve desired effects in future peer-to-peer conflicts. A future interoperable family-of-systems capable of conducting distributed electronic attack, strike, and other missions could reduce the time and cost needed to field new capabilities compared to designing more exquisite weapon systems that are each encumbered with similar mission functionalities.

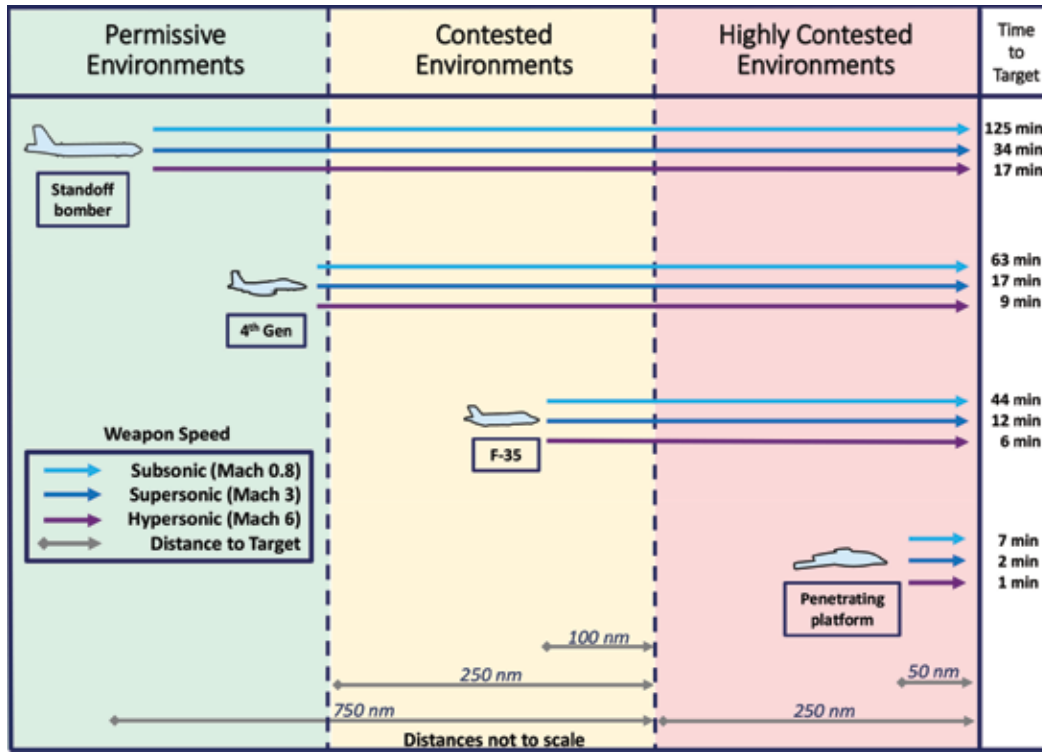
Roll-back approaches to suppressing IADS will be too costly and take too much time. Chinese and Russian IADS are designed to inflict high levels of attrition on U.S. legacy aircraft and weapons. IADS roll-back campaigns using these capabilities would likely result in very high aircraft attrition rates. Alternatively, weapon systems designed to penetrate into highly contested areas will be able to establish temporal, localized air superiority against surface-to-air threats. Penetrating forces complemented by stand-off forces should be able to find and target key IADS weapon systems from multiple directions. This inside-out approach could more quickly attrite an adversary's area-denial capabilities, thereby allowing non-penetrating air capabilities and other forces, including friendly land forces, to bring increased firepower at a higher tempo to the fight.

PGMs suitable for highly contested environments are needed. Most current-generation PGMs were not designed to penetrate against highly capable air and missile defenses and are vulnerable to non-kinetic countermeasures such as GPS jamming and other electronic warfare actions. Future operations into contested and highly contested areas will require a new generation of PGMs, including hypersonic weapons, PGMs with area effects, and weapons for maritime strikes.

225 F-16 fighters were used for defensive counterair operations, as summarized in Chapter 4.

Time to engage targets will be critical. The U.S. Joint Force will need to engage some high-value surface-to-air, air-to-air, and air-to-ground threats in tens of seconds or a few minutes at most. While increasing the speed of a weapon can help reduce engagement times, speed alone may not be able to compensate for very long distances to a target. As shown in Figure 42, very-long-range standoff weapons—even weapons that fly at hypersonic speeds—can take a considerable amount of time to reach their targets. However, platforms that can penetrate contested environments could significantly reduce their weapon flight times. This could increase the survivability of those systems' weapon salvos and their effectiveness against mobile or relocatable targets.

FIGURE 42: ABILITY TO PENETRATE AFFECTS WEAPON TIME-TO-TARGETS



Long-range weapons employment has other kill chain challenges, including the vulnerability of datalinks needed for the weapons to receive updated target information while they are in flight, and the need for them to detect and identify targets that have relocated. Seekers needed to find and characterize targets can also increase a weapon's vulnerability to electronic warfare attacks and other enemy countermeasures. Long-range weapons are generally more expensive than short-range weapons, especially short-range weapons that do not need expensive seekers and datalinks.

There is a need for effective kinetic weapons for SEAD. Although non-kinetic capabilities will be essential to prevailing in future salvo competitions, U.S. forces would greatly

benefit from complementary kinetic threat suppression weapons. The lack of an effective kinetic weapon for SEAD in contested and highly contested environments could embolden adversaries to emit EM signals with near impunity with systems that gather surveillance, acquisition, and targeting data on U.S. air and space forces. Kinetic SEAD weapons would dissuade enemies from emitting and destroy hostile transmitters. This would help increase the effectiveness and survivability of all U.S. forces and weapon systems. Destroying enemy transmitters also reduces the need for U.S. forces to repeatedly suppress the same threats. During a large, long-duration campaign, repetitive electronic warfare actions against the same threats are inefficient, can be unsupportable, and may be unaffordable. Kinetic kills could free SEAD aircraft for other missions and reduce the loss of expensive expendable jammers and decoys.

The overarching measure of merit for future SEAD platforms and their weapons is the time needed to respond to threats. Response times take into account locations of a weapon's launch point, the speed of the weapon to a target, and, to a lesser degree, the trajectory of the weapon. For operations inside contested environments, the driving factor for the location of a weapons launch point is usually the distance a launch aircraft must remain from enemy defenses in order to survive, not the range of its weapon. For non-penetrating aircraft, its survivable standoff distance may be greater than the range of available weapons. Even with a very-long-range weapon, the time it takes for the weapon to reach a target could increase the response time to the point where the target could relocate or otherwise obscure its location.

Overall, the need exists for a future SEAD weapon such as the SiAW. A SiAW with a modest size and speed could be carried internally by penetrating aircraft, help deter enemies from emitting, and could attack threats at close ranges before they can move. This would increase the survivability of U.S. penetrating and non-penetrating platforms and their weapons.

Hypersonic weapons will be in high demand in both theaters. Future hypersonic weapons should be able to target key nodes in an enemy's defenses, as well as circumvent enemy defenses to strike other targets directly. Non-penetrating aircraft carrying the long-range Hypersonic Conventional Strike Weapon now in development could supplement penetrating strikes and create a more complex defensive challenge for Russian and Chinese forces. Standoff attack weapons with greater than five to ten minutes of flight time should be retargetable inflight to increase their effectiveness against targets that can quickly relocate. These weapons should be hardened against enemy jamming and other threats to their communication links. Long-range standoff attack weapons may also need seekers capable of accurately locating and discriminating actual targets from decoys.

In Europe, new area effect weapons capable of attacking multiple land force targets per weapon would help increase the virtual salvo size of individual U.S. strike sorties. The LRASM or a similar follow-on anti-ship weapon carried by bombers and F-35A fighters would give the Air Force the ability to strike maritime targets over long ranges. Mining operations could be another possible mission for stealth bombers that would require new munitions suitable for deployment in contested areas.

A penetrating platform is needed for future SEAD/DEAD operations. Due to the highly mobile nature of many Russian and Chinese air defense systems, a penetrating platform for SEAD/DEAD would reduce threat engagement times and help U.S. air forces achieve the freedom of action needed to conduct strikes, CAS, and other missions in highly contested environments. Improving the survivability of stand-off and stand-in platforms and weapons would increase the operational tempo of U.S. forces, reduce U.S. losses, and possibly shorten campaigns.

During CSBA's workshops and wargame, teams paired the SiAW with a PCA/P-EA aircraft as their primary SEAD/DEAD weapon system for contested and highly contested environments. Operating in concert with multi-domain battle managers using a fused common operational picture gathered from distributed sensors in the battlespace, PCA/P-EA aircraft equipped with SiAW could prioritize and strike high-value dynamic threats. Standoff platforms with JASSM and hypersonic weapons would complement, but not replace the prompt strike capabilities of a stand-in capability. B-21 bombers were not the preferred SEAD/DEAD platforms, since their large payload bays were better suited to deliver weapons on enemy land forces and other large target sets. Instead of using a separate, dedicated P-EA aircraft to support other U.S. penetrating systems, advanced technologies and sensors should support a more distributed approach to electronic attack that uses all platforms and weapons to gain superiority in the EMS domain. This includes a future PCA/P-EA aircraft, which should have the capability to conduct electronic attack and other electronic warfare operations.

Predominately use bombers for high-capacity strikes using less expensive weapons. The wargame teams' operating concepts for both great power conflict scenarios showed a preference for using aircraft with long combat ranges and large payloads of shorter-range weapons that are less expensive than very-long-range standoff weapons for high-volume strikes.

In the Pacific, long-range aircraft would help overcome what is called the tyranny of distance inherent to the region and allow U.S. forces to generate early strike sorties from airfields located further from Chinese missile launchers. U.S. aircraft operating from distant bases would have reduced sortie rates due to the longer-duration sorties that would be necessary to reach targets in the South China Sea and on the mainland compared to aircraft deployed to higher risk bases located closer to China. Using bombers with large weapons payloads for these long-range strikes rather than aircraft with fighter-sized payloads would help compensate for reduced sortie rates. Preferentially using bombers capable of flying thousands of miles without refueling could also help reduce requirements for tanker aircraft relative to using fighter-sized aircraft that have less fuel capacity.

In Europe, combat aircraft with long mission endurance and the capacity to carry large payloads would improve the Air Force's ability to conduct persistent strike operations against thousands of Russian missile launchers, artillery, armored vehicles, and other mobile/relocatable targets. Given Army fires units may require weeks to deploy from the United States, high-volume air strikes would help fill the gap in fires needed to halt Russian ground forces

invading an eastern European NATO state. Range will increasingly be an issue in Europe given Russia's growing ability to launch salvos of precision-guided weapons at NATO airbases over long ranges and Russia's ability to employ A2/AD systems from deep within its territory.

The European wargame team planned to use a significantly larger number of 5th generation fighters and PCA/P-EA aircraft to support strike operations than the Pacific team. This makes sense from an operational perspective, since there are a very large number of military and civilian runways in Europe that are suitable or could be upgraded to support distributed fighter operations. Fighters operating from a distributed posture located closer to the joint operating area would likely have higher sortie rates than more distantly based bombers in the European scenario. They could also require less infrastructure than bombers, which would allow them to more easily disperse and frequently change their operating locations, complicating Russia's strike operations. Furthermore, U.S. F-35A units could leverage the facilities, ground equipment, and other support systems and services that would likely be available at NATO F-35 bases.

Use non-penetrating bombers, fighters, and UAS for standoff operations. Neither wargame team planned to use non-stealth bombers, fighters, and UAS for strike missions in contested and highly contested areas. The teams planned to use non-stealth B-52H bombers for standoff strikes in both theaters. The large weapons capacity of F-15E strike fighters would also make them a valuable means to conduct standoff strikes in the European scenario. F-15Es carrying payloads of future extended-range air-launched decoys and jammers could improve the survivability of penetrating aircraft and help stimulate Russian defenses to activate their sensors or otherwise react in ways that could lead to their detection and targeting.

Unmanned systems are force multipliers. Russia and China could seek to degrade the space-based sensor networks of the United States and other militaries opposing their efforts to seize and occupy areas on their peripheries by force. Penetrating unmanned ISR and strike aircraft with long endurance and the ability to find, fix, and track mobile and relocatable weapon systems in contested environments could help fill the gap created by attacks on U.S. space-based sensor networks. Penetrating ISR and strike aircraft could also be dynamically re-tasked while in flight to detect new threats or strikes against emerging targets.

A balanced stand-in and standoff force structure is needed. Conducting future large-scale strike operations predominately from very-long-range standoff distances would require the use of large numbers of long-range weapons capable of surviving in contested and highly contested environments. To acquire targets that have relocated, these weapons would need either an expensive sensor or a communication package capable of receiving a last-minute update in a jamming environment from a separate sensor platform. In the latter case, sensor systems and their supporting C3 architecture must be resilient and survivable enough to perform their functions in contested areas. In both cases, the cost of all dependencies and their vulnerabilities must be considered. Like aircraft, weapon costs are proportional to their weight and size. The heavier and larger a weapon, the more it usually costs. Therefore, longer-range weapons typically cost more than shorter-range weapons—a point that must be scaled

to a campaign level for affordability comparisons. Very-long-range standoff requirements also drive up weapon size and weight, which reduce the number of weapons that can be carried by a strike aircraft. This would have the effect of increasing the number of sorties and time needed to attack a given quantity of aimpoints. Furthermore, even at hypersonic speeds, flight times of standoff weapons with very long ranges (hundreds of miles) would reduce their operational utility against targets that can quickly relocate or employ their own firepower against U.S. forces before being struck. In summary, a force over-biased toward long-range standoff strike systems would put the future Air Force on the wrong side of the cost curve and decrease its effectiveness. This would play into the hands of a great power's A2/AD strategy.

Organic capability to close the kill chain will be important. Given China's and Russia's informationized warfighting strategies, future Air Force aircraft should have the capability to operate effectively in environments where long-range communications are degraded and locally denied. Penetrating aircraft equipped with sensors and other aircraft mission systems could organically close the kill chain in contested areas and would reduce the impact of Russian and Chinese EMS warfare actions. U.S. air forces could also use highly directional LPI/LPD line-of-sight datalinks such as the Multifunction Advanced Datalink (MADL) or future optical laser communications that are less vulnerable to detection and jamming by enemy forces. Because of their low power and directionality, line-of-sight signals are short range and may be unable to reach receivers that are over the horizon or obscured by terrain. Approaches to relay secure line-of-sight communications could improve the coordination of dispersed air operations. Future aircrews should also be trained to use mission-type orders—ones in which individual units pursue objectives based on the intent of the overall operational commander.[226]

Summary

The majority of the Air Force's current combat aircraft inventory lacks the ability to penetrate and persist in areas covered by Russian and Chinese IADS. To address this shortfall, the Air Force should first develop and assess new operating concepts for strike, SEAD/DEAD, CAS, and other missions for future peer-to-peer conflict scenarios. These concepts should consider how a future family of capabilities could maintain the U.S. Joint Force's strike advantage. This family of capabilities should include future standoff and penetrating PGMs, sensors, datalinks, and other mission systems that will be suitable for operations in contested areas.

This said, upgraded weapons and mission systems alone will not be enough to support large-scale air campaigns against Russia and China. Increasing the Air Force's capacity for penetrating, long-range strikes supported by compatible counterair and electronic attack

226 "Mission command is the conduct of military operations through decentralized execution based upon mission-type orders and is a key component of the C2 function. Its intent is for subordinates to clearly understand the commander's intent and to foster flexibility and initiative at the tactical level to best accomplish the mission." JCS, *Command and Control of Joint Operations*, Joint Publication 3-30 (Washington, DC: JCS, February 10, 2014), p. I-3.

aircraft will also be needed. The shift toward longer ranges, greater survivability, and increased speed of action, as well as the organic ability to close the kill chain in communications-degraded environments, will require the procurement of significant numbers of 5th generation and advanced manned and unmanned aircraft. Recommendations for the size and mix of aircraft in this future force are in Chapter 7. In summary, most of the Air Force's current ISR and strike forces are now best suited for permissive environments as well as the low end of contested operational environments. The future force should shift the Air Force's capacity for ISR, strike, SEAD/DEAD, and related mission areas to platforms and weapons capable of operating in more contested and highly contested environments.

CHAPTER 6

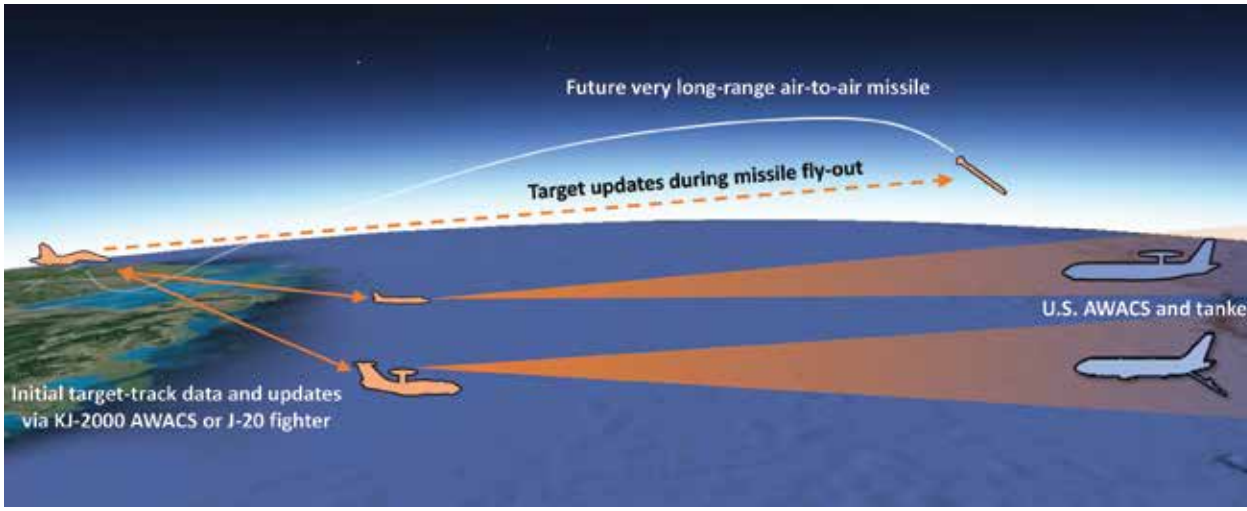
Concepts and Capabilities for Future Air Force ISR, BMC2, Air Mobility, Homeland Defense, and Strategic Deterrence Operations

The Air Force provides aircraft for ISR, BMC2, global air mobility, homeland defense, and strategic deterrence missions that are critical to national defense.[227] Some of these aircraft are considered high-value assets because they play a central role in air operations and are few in number. The increasingly informationized character of warfare places a premium on survivable BMC2 and ISR air systems, a fact that has not gone unnoticed by China and Russia. U.S. air forces are also highly dependent on aerial refueling support, especially for operations over long ranges and to support large-scale dispersed operations in the vast expanse of the Indo-Pacific theater. Both China and Russia have developed the means to attack U.S. AWACS, JSTARS, and air refueling tankers over long ranges in the air and on the ground. As depicted in Figure 43, long-range air-to-air missiles are one of many threats that may force U.S. non-stealth HVAA and tankers to operate from increased standoff ranges from the battlespace, which can decrease the effectiveness of their operations.[228] Additionally, enemy attacks in the electromagnetic spectrum and cyber domain will threaten to disrupt, degrade, deny, or exploit C3 architectures linking these forces.

227 The U.S. Air Force uses the term "rapid global mobility" to describe its aerial refueling and strategic and theater airlift forces and operations.

228 Brian Wang, "The USA Is No Longer Guaranteed Future Military Technology Development," *Military and Commercial Technology*, February 19, 2018, available at https://thaimilitaryandasianregion.blogspot.com/2018/02/the-usa-is-no-longer-guaranteed-future.html.

FIGURE 43: NOTIONAL LONG-RANGE PLAAF AIR-TO-AIR THREATS TO U.S. BMC2 AND TANKER AIRCRAFT



Chapter 6 summarizes potential operating concepts to address these threats and Air Force capabilities and force structure that may be needed to execute them in the future. Chapter 6 also provides insights on the Air Force aircraft inventory needed to defend the homeland and maintain the nation's strategic deterrent posture during great power conflict. Both China and Russia have developed new long-range conventional and nuclear air and missile systems to attack the U.S. homeland. Today, the U.S. military's homeland defense forces lack the capability and capacity to intercept large salvos of cruise missiles and other air threats. In keeping with the scope of this study, the recommendations in Chapter 6 focus primarily on how these threats may affect the size and shape of the Air Force's future aircraft inventory.

ISR, BMC2, and Air Refueling Operations: Future South China Sea Conflict

Assumptions for Theater Basing and Aircraft Survivability

During CSBA's wargame, the Indo-Pacific planning team dispersed most of their ISR, BMC2, and tanker forces to bases outside the First Island Chain to complicate Chinese targeting and reduce the PLA's ability to concentrate its missile salvos on a small number of airbases (see Figure 44).

The wargame team assessed that current airfield logistics infrastructure, airbase active and passive air and missile defenses, and airbase reconstitution capabilities throughout the Indo-Pacific region were inadequate to support high-tempo Air Force ISR, BMC2, and air refueling

operations.[229] Mitigating these shortfalls would require selective hardening of critical base infrastructure, aircraft shelters, and reconstitution investments.

FIGURE 44: INITIAL INDO-PACIFIC TANKER LAYDOWN

Concept for Future ISR and BMC2 Operations

The wargame team developed an approach that could increase the coverage, endurance, and resilience of future U.S. airborne ISR and BMC2 operations. High-signature aircraft such as the E-3 AWACS and E-8 JSTARS would risk extreme levels of attrition if they attempted to operate in contested and highly contested environments; they would likewise lose their ability to cover much of the battlespace if required to operate well outside the range of Chinese long-range air threats.[230] To increase the resiliency of the Air Force's ISR and BMC2 operations in future contested and highly contested environments, the team developed a basic outline of a new architecture that would disaggregate ISR and BMC2 functions across a larger number of platforms and weapon systems (see Figure 45).

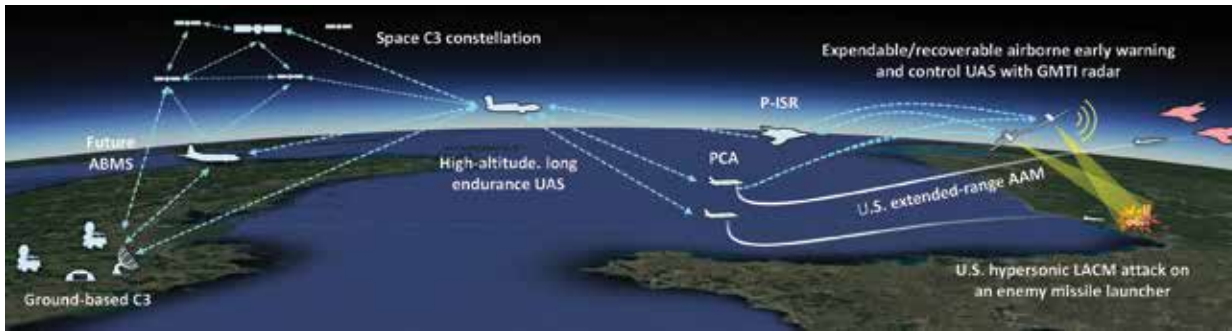
The concept replaces the Air Force's limited number of large manned HVAA with a greater number of smaller ISR and BMC2 platforms, some of which were unmanned and attritable, that could conduct networked, dispersed operations in contested areas. These platforms could be complemented by long-range P-ISR aircraft capable of penetrating and persisting in highly contested threat environments. Combined with smaller, hardened ground stations, persistent and survivable space and cyber forces, and resilient communications, these systems

229 The team assumed that U.S. air forces stationed in the Republic of Korea to deter possible aggression by the Democratic People's Republic of Korea would not be available for operations against China.

230 Operating from standoff distances could greatly reduce their ability to form an accurate picture of the battlespace and manage highly dynamic U.S. air operations.

could constitute an Advanced Battle Management System to support distributed operations in permissive, contested, and highly contested environments.

FIGURE 45: ILLUSTRATIVE CONCEPT FOR FUTURE ISR AND BMC2 OPERATIONS



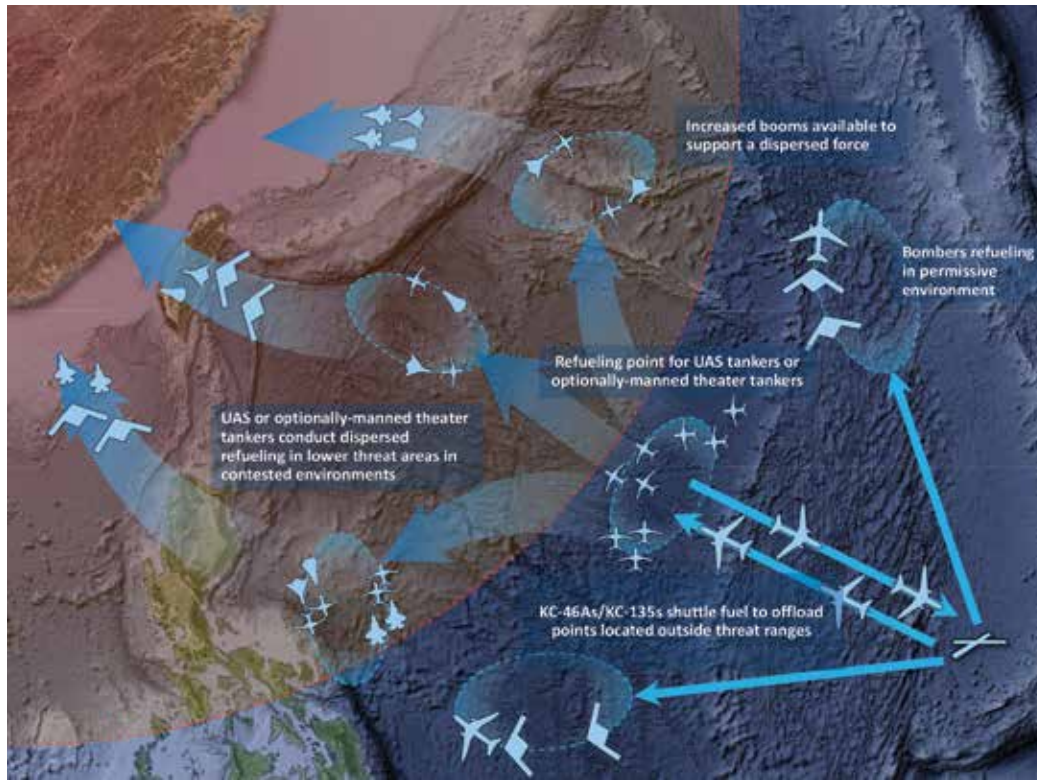
Concept for Future Tanker Operations

The teams chose to use a mix of KC-46As and KC-135s to conduct air refueling in permissive environments, and future smaller and more agile unmanned or optionally manned tankers to refuel U.S. air forces inside lower-risk areas of contested environments. Figure 46 illustrates a concept that takes advantage of the large fuel offload of the KC-46A combined with a new UAS tanker or theater tanker that has some increased survivability characteristics (described later in this section).

As illustrated in Figure 46, KC-46A, KC-135, or lightweight, dedicated tankers would shuttle fuel from secure airbases to UAS tankers or optionally manned theater tankers orbiting at centralized offload points located just outside of the contested environment. Shuttle refueling operations would help extend time on station for the UAS tankers. The smaller UAS tankers would disperse to refuel combat aircraft and other penetrating platforms in lower-threat areas of the contested environment, then return to centralized offload points to refuel again. This concept could help reduce fuel burned by the larger tankers and increase the number of refueling booms available to support air operations over a large area. Figure 46 also shows KC-46As or KC-135s refueling penetrating bombers just outside the contested areas. The Indo-Pacific wargame team planned to use fighters or Unmanned Combat Air Systems (UCAS) as tanker escorts to reduce risk to these operations.

Providing air refueling one or two hundred miles inside contested areas would help extend the range and mission duration of penetrating aircraft, which would have a force-multiplying effect. Moreover, a smaller UAS tanker or the optionally manned theater tanker should be able to operate from a much larger number of military and civilian airfields in the Western Pacific compared to larger wide-body derivative aircraft. This could further improve the future tanker force's ability to refuel a large, dispersed force.

FIGURE 46: CONCEPT FOR REFUELING A DISTRIBUTED FORCE IN PERMISSIVE CONDITIONS AND IN THE LOW END OF A CONTESTED ENVIRONMENT



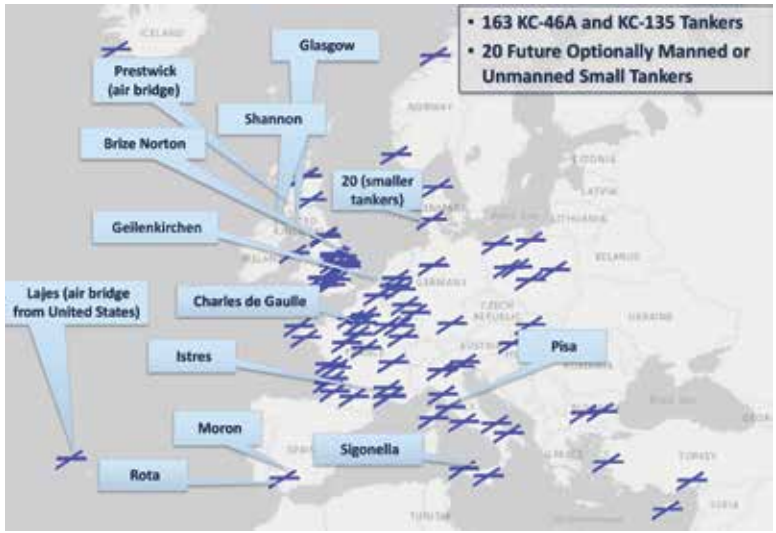
ISR, BMC2, and Air Refueling Operations: Future Baltic Sea Region Conflict

Assumptions for Theater Basing and Platform Survivability

Air Force planners should assume the airbases of ISR, BMC2, and air mobility air forces deployed to Europe to support a major NATO operation against Russia will be subject to air and missile attacks. To complicate Russia's ability to find, fix, track, and target these forces, the European wargame planning team chose to disperse these high-value forces to military and civilian airfields located across Western Europe. To further reduce the risk of attack, the European wargame team planned to operate large ISR, BMC2 and aerial refueling aircraft from airbases at longer ranges from Russian territory than U.S. fighter forces and future unmanned/optionally manned small tankers (see Figure 47).[231]

231 Wargame planning teams considered runway length and width, available parking, fuel, and other base infrastructure to determine viable basing candidates. Although there are numerous airfields in Europe that can be used by military aircraft, only a small subset is suitable for U.S. tankers. That is one of the reasons the wargame planning teams recommended a smaller, optionally manned tanker to be a part of the future air refueling force. The team assumed that Air Force HVAA and tanker aircraft would have permission to transit and operate in Swedish and Finnish airspace.

FIGURE 47: INITIAL EUROPEAN TANKER LAYDOWN



Concept for ISR, BMC2, and Air Refueling Operations

The European wargame planning team adopted a concept very similar to the Indo-Pacific team's approach that disaggregated ISR and BMC2 operations to harden them against Russian air attacks. Instead of relying exclusively on large, vulnerable manned platforms as would presently be the case, the team chose to use an ABMS that included small ISR and BMC2 aircraft, stealth P-ISR aircraft, dispersed and hardened ground stations, and survivable space and cyber forces linked by resilient communications. Both the European and Indo-Pacific wargame teams chose to use a distributed ABMS architecture for operations in areas covered by Chinese and Russian A2/AD systems instead of future large, commercial derivative BMC2 aircraft.

To reduce the risk that long-range Russian air-to-air threats would disrupt U.S. air refueling operations, the team planned to use 4th generation fighters to protect air refueling orbits located in Western Europe. The team also chose to use a future smaller optionally manned or unmanned tanker instead of KC-135Rs and KC-46As to for dispersed air refueling operations closer to the battlespace. Depending on its size and footprint on the ramp, a smaller tanker could have the capability to operate from a greater number of military and civilian airfields compared to KC-135Rs and KC-46As.

Insights on Forces and Capabilities for ISR and BMC2

This section summarizes insights on forces and capabilities requested by the wargame planning teams to support their ISR and BMC2 operating concepts for the future conflict scenarios. Table 20 lists the total PMAI ISR and BMC2 aircraft requested by the teams for their initial operations.

TABLE 20: ISR AND BMC2 AIRCRAFT TO SUPPORT INITIAL THEATER OPERATIONS

ISR and BMC2 Total PMAI Needed in Theater (adjusted for mission capable rates)				2019 PMAI Inventory
Aircraft	Europe Conflict Scenario	Indo-Pacific Conflict Scenario	Total PMAI	
P-ISR	38	78	**116**	0 (potential future)
ABMS	6	10	**16**	0 (potential future)
RQ-4	0	15	**15**	31
RC-135	0	15	**15**	17
MQ-X*	30	20	**50**	0 (potential future)
Multi-Mission UAS*	29	155	**184**	0 (potential future)
*The MQ-X also supported strike operations, and MM-UAS were used as ISR assets and for airbase defense				

PMAI aircraft in the total column in Table 20 were increased to account for an assumed average aircraft mission capable rate of 80 percent for ISR and BMC2 aircraft and 90 percent for tankers. Table 20 includes a future Multi-Mission UAS and future penetrating MQ-X UCAS that would conduct ISR operations in permissive and contested environments respectively. The MM-UAS also supported defensive counterair operations, and the MQ-X was used for strikes and other operations in contested environments.

Major Insights

The following insights on future ISR and BMC2 operations and capabilities informed the aircraft inventory recommendations in this report:

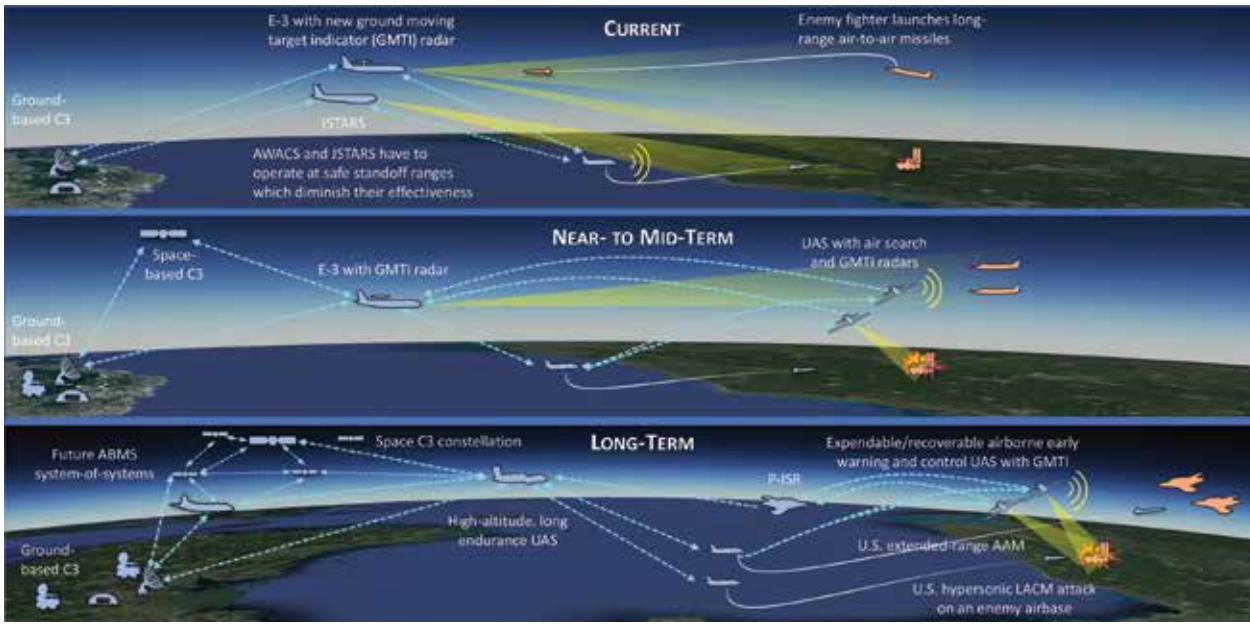
- New operating concepts and capabilities are needed to maintain the advantage in the ISR versus counter-ISR (C-ISR) competition between the U.S. military and Chinese and Russian militaries;
- The Air Force should shift to a resilient ISR and BMC2 multi-domain architecture that includes capabilities in the space and cyber domains; and
- Penetrating UAS could help provide the degree of persistent ISR needed in future dynamic battlespaces to provide information on a very large number of targets that are mobile and can quickly relocate.

Maintaining an advantage in the ISR versus counter-ISR competition. In the era of informationized warfare, great power competitors will continue to improve their ability to rapidly collect and exploit information in the multi-domain battlespace while shaping, degrading, and denying battlespace awareness to adversaries. China and Russia are developing more advanced ISR and BMC2 systems that operate in multiple domains to deny, degrade, deceive, and exploit U.S. and allied information generation and management systems. Chinese and Russian counter-ISR and BMC2 capabilities already threaten current U.S. approaches to these missions, especially operating concepts that rely on using a small number of large HVAA that are vulnerable to air and missile attacks. New operating concepts and capabilities will be needed to ensure the Air Force can provide ISR and BMC2 to the Joint Force in environments that are becoming increasingly contested. These concepts and capabilities should increase the resiliency of U.S. ISR and BMC2 operations on the ground as well

as in the air, as recommended in the airbase air and missile defense section in Chapter 4. Moreover, tremendous increases in the quantity and speed of information in the future battlespace will require a greater reliance on artificial intelligence and new CONOPS to understand and respond to hostile actions.

A more resilient architecture for ISR and BMC2 is needed. It is highly likely that current high-signature ISR and BMC2 platforms attempting to operate in future contested and highly contested environments, depicted at the top of Figure 48, would suffer high levels of attrition.

FIGURE 48: ILLUSTRATIVE EVOLUTION OF BMC2



Herbert C. Kemp, *Rethinking the Information Paradigm: The Future of Intelligence, Surveillance, and Reconnaissance in Contested Environments* (Washington, DC: Mitchell Institute, February 2018), available at http://www.mitchellaerospacepower.org/single-post/2018/02/27/.

Recapitalizing the Air Force's E-3 AWACS and E-8 JSTARS with commercial derivative aircraft would not mitigate this risk. The Air Force should instead develop a family of systems to conduct distributed, networked ISR and BMC2 operations throughout the battlespace.[232] In the near- to-mid-term, as illustrated in the middle section of Figure 48, the force could evolve to incorporate distributed sensors carried by UAS, space systems, and capabilities that operate in cyberspace and other domains. Longer term, the Air Force's ISR and BMC2 architecture should be even more resilient, have greater endurance, and provide more coverage in contested areas. The bottom segment of Figure 48 shows how this future architecture could

232 This approach is consistent with the Air Force's *2030 Air Superiority Flight Plan* recommendation that "the Air Force should develop concepts that disaggregate this capability [BMC2] using multiple sensor platforms, including teamed manned and unmanned systems, a robust battlespace information architecture, and dispersed command and control." U.S. Air Force ECCT, *Air Superiority 2030 Flight Plan*, p.8.

include P-ISR aircraft, manned and unmanned ABMS aircraft, resilient space systems, and hardened or mobile ground stations supported by dedicated high-altitude long-endurance (HALE) UAS to relay communications across the battlespace. The future ABMS should be capable of passively and actively acquiring data from a variety of sources, depending on the threat environment.

Penetrating UAS could help provide the degree of persistent ISR needed in the future. Many targets do not lend themselves to discovery by indirect and inferential means, and U.S. space-based assets cannot always provide the degree of persistence needed to discover, track, and prosecute high-value relocatable targets in contested environments. Whereas earlier ISR concepts were characterized by the need to develop and field persistent, multi-role ISR capabilities for operations in relatively benign conditions, the lethality of the future battlespace will require penetrating and persistent multi-role capabilities.[233] Unmanned P-ISR capabilities equipped with multiple sensors should have sufficient persistence to detect and support the targeting of mobile high-value targets in contested and highly contested airspace. P-ISR aircraft should be equipped with passive sensors to avoid signaling its presence with the emissions of active sensors and utilize LPI/LPD datalinks to exfiltrate data and to network with other systems in the battlespace.

Unlike legacy operating concepts for ISR and BMC2, the future force should not rely on a small number of dedicated P-ISR platforms to maintain the Joint Force's battlespace awareness. All platforms that penetrate contested areas, including 5th and 6th generation fighters and the B-21, should contribute to the air picture by exfiltrating information collected by their sophisticated sensors as they conduct their primary missions.

The importance of the space and cyber domains. The introduction of persistent overhead presence created by the deployment of extensive small-satellite constellations can provide additional imaging and passive electronic intelligence collection and LPI/LPD data paths for exfiltrating data collected by penetrating manned and unmanned aircraft. The Air Force should assess the potential for future constellations of small-satellites in low earth orbit capable of 5G or better data transmission speeds to provide ISR and BMC2 data to weapon systems operating across the battlespace.[234]

233 DoD, *Annual Aviation Inventory and Funding Plan, Fiscal Years (FY) 2015–2044* (Washington, DC: DoD, April 2014), available at http://www.airforcemag.com/DRArchive/Documents/2014/May%202014/doc051914aviationplan.pdf; and U.S. Air Force, *Next Generation ISR Flight Plan Summary* (Washington, DC: U.S. Air Force Headquarters, August 2018), available at https://www.af.mil/Portals/1/documents/5/isrflightplan.pdf.

234 See Troy McLain and Garrit Dalman, "Seize the Highest Hill: A Call to Action for Space-Based Surveillance," *Air & Space Power Journal*, Winter 2018, available at https://www.airuniversity.af.edu/Portals/10/ASPJ/journals/Volume-32_Issue-4/F-McLain_Dalman.pdf.

Insights on Forces and Capabilities for Aerial Refueling

The following section summarizes insights on forces and capabilities requested by the wargame planning teams to support their operating concepts for aerial refueling during CSBA's workshops and wargame.

Summary of Tanker Aircraft for the European and Indo-Pacific Scenarios

Table 21 lists aircraft requested by wargame planning teams to support their initial aerial refueling operations. The "Future Tanker" listed in the first column represents an aircraft the Air Force will likely procure to continue recapitalizing its tanker force after the delivery of 179 KC-46As is completed in the late 2020s.

TABLE 21: AIR REFUELING AIRCRAFT TO SUPPORT INITIAL AIR OPERATIONS

Aircraft	Europe Conflict Scenario	Indo-Pacific Conflict Scenario	Total PMAI
KC-46A equivalents	163	205	**368**
Future Tanker	20	75	**95**
Total	**183**	**280**	**463**

Major Insights

The following insights on future aerial refueling operations and capabilities were developed during workshops and a wargame for two nearly simultaneous conflicts with Russia and China:

- China and Russia will target the Air Force's forward-deployed tanker force on the ground and in the air;
- The current tanker force will be challenged to support distributed joint air operations at scale;
- The tanker force will be challenged to support large-scale, long-range air operations;
- The Air Force tanker fleet is old, and additional delays to its modernization and recapitalization will increase the risk that it will lack the capability and capacity to support the future Joint Force; and
- The Air Force should adopt new approaches to address current and future aerial refueling requirements.

The Air Force's aerial refueling force is increasingly vulnerable on the ground and in the air. Bases now used by Air Force tankers in the Indo-Pacific region and Europe lack high-capacity active defenses, hardened shelters, and other passive measures to defend

against air and missile attacks.[235] Furthermore, a large portion of the Air Force and Defense Logistics Agency's fuel storage and distribution architecture that support air refueling is unhardened and has little redundancy.[236] Even modest enemy strikes against these bases and infrastructure could greatly reduce the Air Force's ability to sustain large-scale forward aerial refueling operations. Lastly, KC-135s, KC-10s, and KC-46As cannot operate in contested air environments. Although fighter CAPs could help protect aerial refueling operations, Chinese and Russian long-range sensors and air-to-air missiles will make it more difficult to detect, prevent, and maneuver away from attempted intercepts. Integrating sensing, communications, networking, and some self-defense capabilities on future tankers or their escort aircraft could help reduce the risk of air-to-air attacks.

The current tanker force will be challenged to support distributed joint air operations at scale. Emerging joint concepts emphasize the need to deploy U.S. air forces to geographically dispersed postures to support distributed air operations that complicate enemy attacks.[237] These will stress the capability and capacity of the Air Force tanker force in at least four ways.

First, all of the Air Force's current tankers must operate from long, reinforced runways that can support their heavy gross weights. This limitation is particularly acute in the Indo-Pacific region, where there are fewer airfields capable of supporting Air Force tanker operations than there are in Europe. The development and fielding of smaller manned or unmanned tankers capable of operating from shorter, smaller, and less improved runways, taxiways, and parking areas could significantly reduce the tanker force's tether to a small number of operating locations.

Second, because the Air Force and Defense Logistics Agency's fuel storage infrastructure is concentrated at a small number of forward airbases, is generally unhardened, and lacks redundancy, tankers that *could* disperse to other airfields would likely lack the bulk fuel storage and distribution capabilities needed to support their operations. Although the Air Force has experimented with concepts such as Rapid Raptor and Agile Combat Employment that use airlift aircraft (principally C-17s) to transport fuel in bladders to refuel fighters at temporary airfields, it would be difficult to scale these concepts to support a large air campaign.[238]

235 The lack of high-capacity active defenses, hardened shelters, and other passive defensive measures may be the most significant threat to U.S. military air operations in the Indo-Pacific region in the near term.

236 Given China's and Russia's conventional long-range strike capabilities, this is a concern for all U.S. forces in the Indo-Pacific region and Europe.

237 Air Force concepts consistent with this approach include Adaptive Basing and Agile Combat Employment. Eric Donner, "Seven Nations, Joint Partners Address Great Power Competition at Summit," *U.S. Air Force News Service*, October 2, 2018, available at https://www.af.mil/News/Article-Display/Article/1651616/seven-nations-joint-partners-address-great-power-competition-at-summit/.

238 Amy McCullough. "Rapid Raptor 2.0," *Air Force Magazine*, March 7, 2017, available at http://www.airforcemag.com/DRArchive/Pages/2017/March%202017/March%2007%202017/Rapid-Raptor-2.0.aspx.

Pre-positioning expeditionary fuel bladders as well as bulk land and maritime fuel delivery and distribution operations would help reduce this capability gap.

Third, the current tanker fleet will have difficulty refueling air forces that are conducting all-aspect, distributed operations over very large areas against China or Russia. This challenge would be magnified by launching pulses of aircraft from different areas in a theater simultaneously to overwhelm an enemy's defenses. These operations could increase requirements for booms in the air in dispersed locations that exceed the capacity of the current force.[239] Currently, Air Force tankers are only capable of transferring fuel to one or a small number of aircraft at a time, depending on their transfer modality.[240] The ability to generate enough booms in the air to support future large-scale distributed air operations will be as important as having enough fuel offload capacity.

Fourth, it is probable that the Navy will require a significant increase in aerial refueling support from the Air Force. This increase will stem in part from the need to support long-range carrier air wing operations and Navy P-8 maritime patrol aircraft that are being fitted with aerial refueling receptacles, a feature the Navy's P-3 maritime patrol aircraft lacked.

The tanker force will be challenged to support long-range air operations at scale. Three major shortfalls would inhibit the tanker force's ability to support future large-scale air operations over long ranges against China or Russia. In addition to the lack of suitable runways and fuel infrastructure for tanker operations, it is likely that demand for long-range, aerial refueling air bridges to support the continuous movement of bombers, long-range ISR aircraft, and other forces between distant bases, combined with other refueling needs, will outstrip the current tanker force's capacity. Moreover, the planned retirement of the KC-10 tanker fleet will reduce the refueling force's ability to support long-range operations until the KC-46A force is operational. It is expected the Air Force will start to retire the KC-10 upon introduction of the KC-46A. Although KC-46As have a slightly greater fuel capacity than the KC-135, they have significantly less fuel capacity and fuel offload capacity than the KC-10.[241]

The tanker fleet is old and its recapitalization has been delayed. The size of the Air Force's tanker force is at a historic low, and its average age is the highest of any aircraft fleet in DoD. The planned procurement of approximately 15 new tankers per year would almost certainly require KC-135Rs to remain in the inventory until well past 2040, especially if DoD

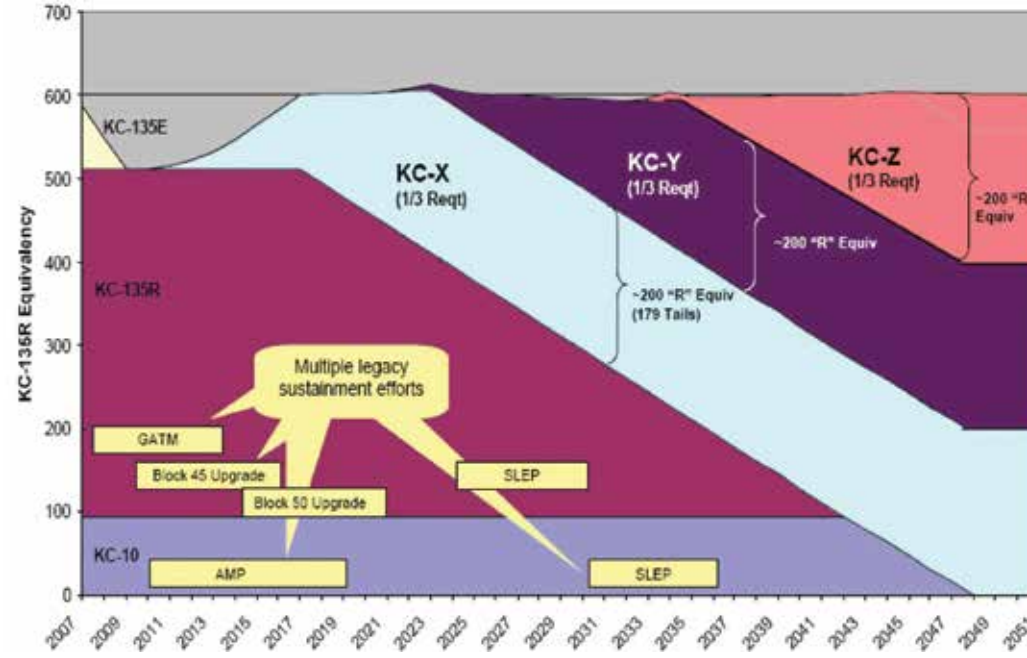
239 "The boom is a rigid, telescoping tube that an operator on the tanker aircraft extends and inserts into a receptacle on the aircraft being refueled." Christopher Bolkom, *Air Force Aerial Refueling Methods: Flying Boom versus Hose-and-Drogue* (Washington, DC: Congressional Research Service, June 6, 2006), available at https://fas.org/sgp/crs/weapons/RL32910.pdf.

240 Some Air Force tankers can transfer fuel to one or more Navy, Marine Corps, or Air Force special operations aircraft simultaneously using a hose-and-drogue method of fuel transfer.

241 The KC-10 can carry a maximum fuel capacity of 356,000 lb; the KC-135 can carry 200,000 lb; and the KC-46A can carry 212,000 lb. See Appendix A for more details. The KC-46A's and KC-10's ability to receive fuel while airborne improves their ability to support long-range air operations. Only a small number of specialized KC-135T tankers have the capability to be refueled while airborne.

air refueling requirements increase. According to the tanker recapitalization plan illustrated in Figure 49, the Air Force anticipated the KC-46A—previously referred to as the KC-X—would join the force beginning in 2010.

FIGURE 49: AIR FORCE'S LONG-STANDING TANKER RECAPITALIZATION PLAN



This graphic is from an unclassified slide developed by the Office of the Assistant Secretary of the Air Force for Acquisition, Technology & Logistics (SAF/AQ) in the 2005 timeframe. The slide appears in numerous Air Force briefings on its future tanker force. It can also be found publicly at https://www.everycrsreport.com/files/20080228_RL34398_22a39422298aa9a93f4e709aae612c99011e9980.pdf.

The Air Force accepted delivery of its first KC-46A in January 2019. Further delays to the procurement of the KC-46A or follow-on KC-Y and KC-Z tankers could have a major impact on the Air Force's ability to support refueling requirements of the Joint Force.

The Air Force should develop new approaches to meet its future air refueling operational requirements, informed by analyses of challenges facing its current aerial refueling enterprise.

On the ground, the Air Force should improve its aerial refueling posture by increasing the number of airfields in the Indo-Pacific region and Europe that tankers can operate from. In conjunction with DLA and other Services, the Air Force should improve its ability to receive bulk fuel at different locations, including via ship, intra-theater barges, and over-the-shore connectors. Similar to theater bases hosting U.S. combat air forces, DoD should selectively harden ground support infrastructure, improve airbase reconstitution capabilities, possibly construct hardened aircraft shelters for tankers, and take other measures to defend the tanker force against air and missile strikes.

In the air, the Air Force should improve the ability of its tanker force to support distributed air operations over large areas and in contested environments. Given the age of the current tanker force and the time required to develop and field new aircraft, the Air Force will need to consider alternatives and quickly commit to fielding a follow-on to the KC-46A that can operate from more airfields and is efficient, affordable, and more survivable. Conducting aerial refueling inside lower-risk areas of contested airspace, if possible, would be a force multiplier. In addition to improving the survivability of some KC-46A tankers by giving them communications, networking, improved situational awareness, and possibly some self-defense systems, the Air Force should consider the following options for a follow-on tanker (see Appendix A for more details).

- **A small, unmanned tanker.** The Air Force should assess the operational value of small, reduced-signature unmanned tankers that could operate in the lower-risk areas of contested environments. The Air Force could leverage other developmental programs to develop an unmanned tanker that would complement manned air refueling aircraft. Based on state-of-the-art technologies, a refueling UAS capable of offloading approximately 30,000 lb of fuel at a range of 500 nm or more could be developed and begin production before 2030. These tankers could extend air refueling for some distance into the contested environment at lower risk compared to using manned tankers.

- **A theater tanker.** The Air Force should consider the need for an optionally manned or unmanned tanker that is smaller and more fuel efficient than current tankers to support large-scale distributed air operations.[242] A smaller tanker could have approximately 50 percent of the ramp spot factor of a KC-135R, runway and surface type requirements similar to C-130s, the capacity to offload approximately 60,000 lb of fuel at a range of 750 nm, and passive defenses that would enable it to penetrate for some distance into contested areas.[243]

- **A lightweight, dedicated tanker.** Another option would be to develop a dedicated air refueling tanker without the capacity to carry cargo. A lightweight dedicated tanker could be designed to have a C-130 footprint on the ground and greater fuel efficiency than current-generation tankers, which would improve its ability to provide large fuel offloads over long ranges.[244]

242 These tanker aircraft could be designed to carry cargo, or they could be dedicated tankers. Based on Barth Shenk, "Advanced Tanker Concepts and Enabling Technologies," PowerPoint briefing, Air Force Research Laboratory/RQV, provided to CSBA on October 16, 2018.

243 A tanker with a C-130 ground footprint may be able to operate from twelve times as many airfields in the Western Pacific as KC-135 tankers. Based on Shenk, "Advanced Tanker Concepts and Enabling Technologies."

244 Michael Stocksdale, "Lightweight Tanker Concept," PowerPoint briefing, Air Mobility Command/A10, provided to CSBA on October 16, 2018. Stocksdale's tanker concept is his own and does not represent the Air Mobility Command or the official position of the Air Mobility Command, the Air Force, or the Department of Defense.

Insights on Forces and Capabilities for Airlift

The Joint Force relies on Air Force airlift assets to deploy and sustain its military operations worldwide. The Air Force's strategic airlift force transports personnel, supplies, and equipment intercontinentally or across regions, and its tactical airlift forces transport the same within theaters. With a few exceptions, the Air Force has recapitalized and modernized its strategic and tactical airlift forces since the end of the Cold War. The Air Force accepted delivery of its last of 223 C-17s in 2013, and it has completed modernizing its C-5s. Based on current estimates, the Air Force will not need to begin replacing its C-5Ms and C-17s until just a few years prior to 2040, assuming there are no major increases in airlift requirements or unforeseen service life issues.

Major Insights

Workshop and wargame planning teams developed two significant insights on future airlift forces and capabilities needed to support their future operating concepts. First, the Air Force's airlift assets deployed or operating into forward airbases will be highly vulnerable to Chinese and Russian attacks. Second, a shift toward conducting highly distributed joint operations in the Indo-Pacific region and Europe will likely increase the U.S. military's future strategic and tactical airlift requirements.

The Air Force's airlift force will be vulnerable to Chinese and Russian attacks. Airlift assets deployed to airfields within the operating range of Chinese or Russian strike systems will risk high rates of attrition while on the ground. In the air, the large signatures and slow speeds of strategic and tactical airlift aircraft make them highly vulnerable to attack in contested environments. Consequently, operating concepts and tactics, techniques, and procedures for airlift forces will need to evolve to increase their survivability.

Future distributed operations will likely increase the Joint Force's need for airlift. As previously mentioned, the Air Force has expressed interest in concepts to operate its air forces from a larger number of distributed locations within and across theaters, including civilian and temporary airfields. Airlift will be a critical enabler of distributed operations, transporting forces, supplies, equipment, and other assets to alternative airfields as well as to the dispersed locations of other elements of the Joint Force. Collectively, operating U.S. forces from highly distributed postures in the Indo- Pacific region and in Europe could increase requirements for Air Force strategic and theater airlift. The unclassified executive summary of DoD's 2018 Mobility Capability Requirements Study (MCRS) states that DoD's current and planned mobility force structure will be sufficient through 2030. Additional analysis may be needed to determine how future global air mobility requirements should change

to support new joint operating concepts and address evolving threats to the Air Force's mobility operations.[245]

Insights on Forces and Capabilities for Homeland Defense

Since the earliest days of the Cold War, air defense of the U.S. homeland has been a challenging and resource-intensive proposition for the Air Force. In response to the Soviet Union's development of a long-range bomber force in the 1950s, the Air Force developed the Radar Fence Plan, which projected a requirement for building 411 radar sites and 18 air defense control centers across the Continental United States.[246] Due to the plan's high cost, the Air Force reverted to a concept to defend a limited number of key areas coupled with the ability to launch a strong offensive response to attacks on the homeland. In 1957, Canada and the United States established the North American Air Defense Command (NORAD), which subsequently became the North American Aerospace Defense Command, to defend continental Canada and the United States. Over time, NORAD adopted an approach of intercepting enemy bombers as far as possible from the United States and Canada, then presenting an air defense-in-depth inside NORAD airspace.

Air and missile threats to the U.S. homeland are far different today than during the Cold War. In addition to ICBM and submarine-launched ballistic missile (SLBM) threats, Russian bombers are able to launch long-range land attack cruise missiles against targets in the United States without penetrating NORAD airspace.[247] Moreover, submarine-launched cruise missiles from Russia have reemerged as threats to the U.S, homeland along with other novel weapons like hypersonic cruise missiles launched by Russian bombers. LACMs launched by Russia's long-range bombers could reach targets located in North America, which is a major concern given the lack of sufficient cruise missile defenses in the U.S. homeland.[248] In addition, China is expected to field the H-20, an intercontinental stealth bomber that will likely carry long-range cruise missiles.

245 United States Transportation Command, "Mobility Capabilities and Requirements Study (MCRS) 2018, Executive Summary," *Inside Defense,* February 1, 2019, available at https://insidedefense.com/sites/insidedefense.com/files/documents/2019/feb/02052019_mcrs.pdf. See also Courtney Albon, "New Mobility Requirements Study Projects No Growth in DOD Airlift, Tanker Capacity," *Inside Defense*, February 5, 2019, available at https://insidedefense.com/daily-news/new-mobility-requirements-study-projects-no-growth-dod-airlift-tanker-capacity.

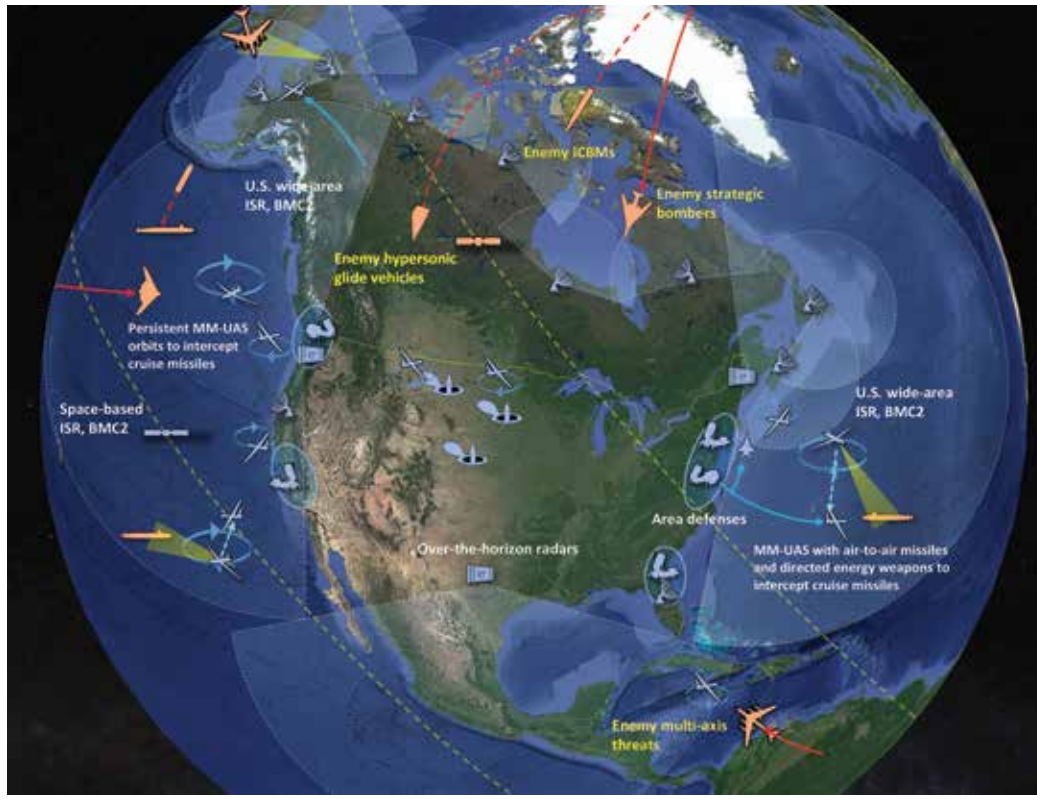
246 Kenneth Schaffel, *The Emerging Shield: The Air Force and the Evolution of Continental Air Defense, 1945–1960* (Washington, DC: Office of Air Force History, 1990), p. 70, available at https://apps.dtic.mil/dtic/tr/fulltext/u2/a246702.pdf.

247 General Lori Robinson, Commander U.S. Northern Command and North American Aerospace Defense Command, statement before Senate Armed Services Committee, February 15, 2018, p. 11, available at http://www.northcom.mil/Portals/28/Robinson_02-15-18%20SASC%20Testimony.pdf?ver=2018-02-15-105546-867.

248 "Russia has prioritized the development of advanced cruise missiles capable of holding targets within North America at risk from distances not previously seen. These systems present an increasing threat to North America…and the limited indications and warnings likely to be seen prior to a combat launch." General Lori Robinson, Commander U.S. Northern Command and North American Aerospace Defense Command, statement before Senate Armed Services Committee, February 15, 2018, p. 11, available at http://www.northcom.mil/Portals/28/Robinson_02-15-18%20SASC%20Testimony.pdf?ver=2018-02-15-105546-867.

During CSBA's wargame, an air planning team developed a concept for meeting the Air Force's Aerospace Control Alert (ACA) requirements and countering a limited number of Chinese and Russian long-range cruise missile attacks.[249] This approach established an alert posture of interceptor aircraft supported by BMC2 and air refueling aircraft that could rapidly react to air and missile threats (see Figure 50).

FIGURE 50: CONCEPT FOR FUTURE HOMELAND AIR AND MISSILE DEFENSE



The team and subsequent post-wargame analysis estimated that defending a small number of critical areas from cruise missile attacks could require about 140 F-16 equivalents teamed with 30 MM-UAS, 45 KC-46A equivalents, and a number of airborne early warning aircraft or ABMS.[250] This force was representative of requirements to defend the homeland against

249 In September 2011, NORAD stopped using the term Air Sovereignty Alert (ASA) and created a new term, Aerospace Control Alert. ACA includes dedicated fighter aircraft and personnel at steady state alert sites across Canada and the United States, as well as the aerospace control mission. Aerospace control combines the air sovereignty mission, which is to know and control what is flying in Canadian and U.S. airspace, and air defense mission, which is to take measures designed to defend against attacking enemy aircraft or missiles. See U.S. Government Accountability Office (GAO), *Continued Actions Needed to Improve Management of Air Sovereignty Alert Operations* (Washington, DC: GAO, January 12, 2012).

250 A Defended Asset List (DAL) is the list of assets that a commander chooses to attempt to defend at varying levels. The DAL is drawn from a larger list of critical assets known as the Critical Asset List.

cruise missile attacks. Defending a larger number of areas would likely deplete the Air Force's aircraft inventories for other critical missions. This representative force could, however, cause China and Russian to honor the threat and choose between not attacking the U.S. homeland or launching much larger attacks to ensure they succeed. The latter course of action would be highly escalatory, a fact that may deter Chinese or Russian attacks.

Major Insights

The following insights are intended to inform Air Force assessments of its future operating concepts and aircraft inventory requirements for homeland defense.

- Using significant numbers of 5th generation aircraft to support homeland defense missions is not necessary and could reduce their readiness for high-end conflict;
- Improved wide-area ISR and BMC2 capabilities may be needed to defend against multi-aspect air attacks on the homeland; and
- A future homeland defense force should include a cost-effective mix of manned and unmanned systems.

There are opportunity costs associated with using 5th generation aircraft for homeland defense. The Air Force's current approach to homeland defense uses a considerable portion of its F-22A air superiority force for alert missions in Alaska and Hawaii. This decreases their readiness for high-end operations.[251] Moreover, the growing threat of cruise missile attacks on the homeland could increase the Air Force's alert requirements. The Air Force should consider alterative platforms, possibly including UAS or even a modified variant of its future T-X trainer, to support these requirements and reduce or eliminate the need to maintain F-22As on alert status.

Wide-area ISR and improved BMC2 capabilities are needed to defend against air attacks. The future homeland defense architecture will require wide-area, long-endurance surveillance capabilities that can detect, track, and support the targeting of incoming enemy bombers and cruise missile salvos. This will require long-range ground-based, airborne, and space-based sensors to provide persistent, redundant coverage and BMC2 capabilities to support NORAD responses. A disaggregated BMC2 architecture consisting of a mix of airborne and terrestrial systems could be more resilient against attacks and possibly less expensive to acquire and operate than an all-airborne architecture.

A future homeland defense force should include a cost-effective mix of manned and unmanned systems. Novel approaches to intercepting multi-access air attacks over long ranges on the U.S. homeland should include the use of space systems, airborne wide area sensors, and airborne and ground-based networked BMC2 capabilities. A force of 4th

251 GAO, *F-22 Organization and Utilization Changes Could Improve Aircraft Availability and Pilot Training* (Washington, DC: GAO, July 2018), available at https://www.gao.gov/assets/700/693279.pdf.

generation fighters and multi-mission UAS equipped with surveillance pods, long-range air-to-air missiles, and, in the future, high-energy lasers could be postured at strategically sited airbases to scramble on warning of potential air attacks. Given China's and Russia's maturing ability to strike with precision over very long ranges, the U.S. homeland will not be an operational sanctuary.[252] Future requirements for defense of the homeland will overlap with the Air Force's other requirements. The Air Force should appraise emerging air threats to the U.S. homeland and develop approaches that will improve the resiliency of NORAD's air defenses. These approaches could include attack operations to reduce the density of enemy threats and a mix of lower-cost manned and unmanned aircraft to intercept airborne threats.

Insights on the Future Air Force Nuclear Deterrence Force

The Air Force is required to organize, train, and equip forces to "conduct nuclear operations in support of strategic deterrence, to include providing and maintaining nuclear surety and capabilities."[253] The Air Force maintains a force of Minuteman III ICBMs, nuclear weapons-capable B-52H and B-2 bombers, and a limited number of dual-capable fighters that can deliver nuclear gravity bombs to meet its strategic deterrence requirements. These nuclear-capable forces are supported by air refueling tankers, E-4Bs that serve as a National Airborne Operations Center to maintain command and control over the nation's nuclear forces in a crisis, and a fleet of rotary wing utility aircraft to support operations of the Air Force's ICBM wings.

Consistent with the force planning construct recommended in Chapter 3, aircraft needed to sustain strategic deterrence should be additive to the inventory required for conventional warfighting and homeland defense. Accordingly, Chapter 7 recommends fencing off or withholding a number of nuclear-capable bombers and their supporting tankers from deploying to support large-scale conventional operations to defeat great power aggression. These recommended withholds are notional and intended to illustrate the additive nature of strategic deterrence requirements. Additional or fewer bombers and tankers could be withheld depending on the nature of the crisis and national priorities. It is also important to note that the health of the Air Force's Minuteman III force and viability of nuclear ALCMs carried by its B-52Hs could change future bomber requirements. Failure to develop and begin fielding

252 "The ability to deter and defeat threats to our citizens, vital infrastructure, and national institutions starts with successfully detecting, tracking, and positively identifying targets of interest approaching and within U.S. and Canadian airspace in the homeland." General Lori Robinson, statement before Senate Armed Services Committee, February 15, 2018, p. 10, available at http://www.northcom.mil/Portals/28/Robinson_02-15-18%20SASC%20Testimony.pdf?ver=2018-02-15-105546-867.

253 "Functions of the Department of Defense and its Major Components," DoD Directive 5100.1, December 21, 2010, p 34, available at https://fas.org/irp/doddir/dod/d5100_01.pdf.

replacements for both the Minuteman III and ALCM by 2030 or shortly thereafter would have the effect of greatly reducing the viability of ICBM and bomber legs of the strategic triad .[254]

Summary

The preponderance of the Air Force's current ISR, BMC2, air refueling, and airlift aircraft lack the ability to operate in contested and highly contested environments. Historically, these capabilities have been critical to the success of U.S. power projection operations; they are now at risk of becoming the focus of Chinese and Russian attacks that could hobble future operations. Sustaining America's ISR, BMC2, and aerial refueling advantages will require more than modernizing systems on existing aircraft or recapitalizing existing aircraft with platforms designed to operate as they have in the past. Instead, the Air Force should adopt new concepts and capabilities for conducting ISR, BMC2, and aerial refueling operations. It should also consider the changing requirements for strategic and tactical airlift that result from maturing concepts for conducting multi-domain operations and other joint and Service-specific approaches to future warfare. The ability to support highly dynamic, distributed joint operations in future battlespaces should be a major driver of the capabilities and capacity of these aircraft inventories.

To defend the homeland, DoD should continue to conduct rigorous appraisals of emerging threats, such as air-launched cruise missile attacks on the United States, then determine how it should best allocate its resources toward defending forward and capabilities to defend in the air at home. Promising approaches will require a mix of attack operations to reduce enemy air threats at their source, active defenses to intercept launch platforms and munitions attacking the homeland, and possibly passive defenses to limit damage from attacks.

Lastly, maintaining a robust, credible and effective strategic deterrence posture will require a force of tankers, nuclear-capable bombers, and specialty aircraft. The overall size of these aircraft inventories should be a function of what will be needed sustain strategic deterrence as well as to defeat great power aggression in the future.

254 For details on the pressing need to replace the Air Force's Minuteman III ICBMs and nuclear-capable ALCMs, see Mark Gunzinger, Carl Rehberg, and Gillian Evans, *Sustaining the U.S. Nuclear Deterrent: The LRSO and GBSD* (Washington, DC: Center for Strategic and Budgetary Assessments, 2018).

CHAPTER 7

Summary of Future Aircraft Inventory Recommendations

Insights and recommendations in Chapter 7 are organized into three parts. Part one summarizes a future aircraft inventory that is aligned with the force planning construct for the Air Force proposed in Chapter 3. The planning construct prioritizes the development of a force with a mix of capabilities and the capacity to fight two major great power conflicts, support homeland defense, and sustain strategic deterrence.

The second part of Chapter 7 begins by presenting a baseline Air Force aircraft inventory for FY 2030 that is a CSBA projection of the Service's FY 2019 inventory extended over the next two Future Years Defense Programs (FYDP). This baseline considers likely aircraft procurement rates and planned or potential retirements between FY 2020 and FY 2030. We then make recommendations as required by the 2018 NDAA for a 2030 inventory. Recommendations to accelerate or initiate some new acquisition programs are informed by the maturity of technologies and the potential capacity of the defense industrial base, not by projections of funding that may be available to the Air Force. The recommended 2030 inventory is a waypoint toward building a future force that shifts the Air Force toward a mix that would be better capable of operating in contested and highly contested environments.

Part three of Chapter 7 summarizes the results of a Strategic Choices Exercise to explore how different budget levels could affect the types of tradeoffs the Air Force might consider and how quickly it could field a future force capable of supporting the recommended force planning construct. This exercise tasked four teams composed of military planners and operations experts to rebalance the Air Force's force structure and major acquisition programs over a ten-year period (FY 2020–2029). Each team was given a different ten-year budget profile—projected budget minus $4 billion per year, projected budget, projected budget plus $4 billion per year, and projected budget plus $8 billion per year through 2029.

Part 1: Shaping and Sizing the Future Force

Aircraft Inventory to Fight Two Great Power Conflicts Nearly Simultaneously

Table 22 summarizes the combat, ISR, and BMC2 primary mission aircraft inventory needed to support the CONOPS developed by the wargame teams to defeat Chinese and Russian aggression.[255] This notional force includes B-21 bombers capable of teaming with penetrating counterair and electronic attack aircraft to attack Chinese and Russian targets from multiple aspects in highly contested environments.

TABLE 22: COMBAT, ISR, AND BMC2 PRIMARY MISSION AIRCRAFT INVENTORY FOR TWO NEARLY SIMULTANEOUS GREAT POWER CONFLICTS

Aircraft	Europe Conflict Scenario	Indo-Pacific Conflict Scenario	Total PMAI	Notes
B-2	15	0	15	
B-21	86	106	192	
B-52H	30	52	82	44 PMAI in the FY2019 inventory
F-15E	100	0	100	
F-16	40	120	160	
F-22A	137	30	167	123 PMAI in the FY2019 inventory
F-35A	265	321	586	
PCA/P-EA	115	85	200	
MM-UAS	29	155	184	
MQ-X	30	20	50	
RQ-4	0	15	15	
P-ISR	38	78	116	
RC-135	0	15	15	
ABMS	6	10	16	

The forces in Table 22 represent a break from the orthodoxy of traditional U.S. combat air operations. To cite one example, U.S. bombers have historically conducted strike missions against large, relatively fixed targets such as industrial complexes, airfields, and massed enemy forces. Other missions to suppress air defenses, interdict enemy ground forces, and provide close air support to friendly forces have been carried out by fighter/attack aircraft. Operating concepts created by workshop and wargame teams repeatedly used penetrating bomber aircraft for all of these missions. Aircraft with advanced stealth, long range, and the ability to carry large payloads of weapons were viewed as well-suited for operations against Russian and Chinese forces in contested and highly contested environments.

In another break with precedent, PCA/P-EA aircraft used by wargame teams are combined into a *single* multi-mission weapons system in Table 22. As recommended in Chapter 4, future penetrating aircraft should be capable of defeating air-to-air and air-to-surface targets, conducting electronic attacks, and performing other electronic warfare tasks. Fielding

255 PMAI inventories in Table 22 have been adjusted for mission capable rates.

different aircraft for these operations would run counter to technological trends toward developing multi-function aircraft mission systems that can perform as active and passive sensors, jammers, and communications systems.[256] Furthermore, creating a single program to develop and procure a multi-mission PCA/P-EA aircraft would be less expensive than developing, procuring, and sustaining two different weapons systems.

The force structure in Table 22 would shift the Air Force aircraft inventory's center of mass toward long-range systems capable of operating in highly contested environments. Preferentially using long-range penetrating bombers for strike against China's fielded forces would mitigate the inherent tyranny of distance of the Pacific theater and reduce the Air Force's reliance on forward bases vulnerable to air and missile attacks. Due to the magnitude of air and missile threats against airbases located along the First Island Chain in the Pacific, bombers operating from more geographically distant bases should make up the bulk of U.S. offensive airpower early in a future conflict with China. Long-range aircraft with large payloads and the ability penetrate would also increase the Joint Force's ability to strike well-defended hardened, deeply buried, and mobile/relocatable targets with large numbers of less expensive, direct attack or stand-in weapons. Furthermore, the scale of the potential target set in a conflict with China would make bombers carrying large payloads the more efficient option for long-range strikes compared to using aircraft with much smaller fighter-sized weapon payloads.

Although threats to airfields and air refueling tankers may be less acute in Europe than in the Pacific, a major Russian offensive against one or more Eastern European NATO states could include attacks against ground and sea lines of communication in Western Europe that would significantly delay the arrival of U.S. and NATO land forces in the joint operating area. In this situation, the mix of long-range, penetrating and persistent forces in Table 22 could operate from airfields located in lower-threat areas to conduct high-tempo, multi-domain operations to halt invading Russian land forces, provide fire support from the air to friendly forces, and degrade Russia's area-denial systems at the start of conflict.

Similarly, PCA/P-EA and P-ISR aircraft should be able to operate from lower-risk areas and have longer ranges and mission persistence than current fighters. PCA/P-EA aircraft that degrade airborne and surface-to-air threats would reduce the risk to U.S. penetrating strike platforms and weapons in both 2035 scenarios. Penetrating ISR aircraft with long ranges and mission persistence would help ensure other penetrators receive current information on the disposition of enemy forces, emerging threats, and mobile/relocatable targets. P-ISR that can persist in contested areas would reduce the U.S. Joint Force's reliance on increasingly vulnerable overhead sensor networks and would be more responsive to the dynamic conditions of the future battlespace.

256 For more information on these technologies, see Clark and Gunzinger, *Winning the Airwaves*.

Each of the 16 Advanced Battle Management Systems in Table 22 is a multi-domain system-of-systems capable of conducting distributed battle management operations in contested environments, not discrete aircraft. The Air Force's BMC2 force now consists of large, non-stealth aircraft that are highly vulnerable to surface-to-air and air-to-air attacks and require a large supporting tail of fighter and tanker aircraft. Using commercial derivative aircraft to perform this mission in future contested and highly contested environments would not be feasible. Moreover, sensors on non-stealth BMC2 aircraft like the E-3 AWACS and E-8 JSTARS that need to standoff 500 nm or more from Russian threats and 800 nm or more from Chinese IADS cannot reach critical areas of the battlespace.

Table 22 also includes a significant number of Multi-Mission UAS and F-16 fighters. Wargame teams allocated the MM-UAS and the Air Force's remaining F-16s toward defending U.S. airbases against air and missile attacks, not offensive operations. This was an acknowledgement by the teams that the Air Force cannot continue to assume its theater airbases will be immune from attack, or that another Service will provide enough air and missile defense capacity to counter Russian and Chinese strikes.

TABLE 23: AIR REFUELING AIRCRAFT TO SUPPORT FORCES ALLOCATED TO THE INDO-PACIFIC AND EUROPEAN CONFLICTS

Aircraft	Europe Conflict Scenario	Indo-Pacific Conflict Scenario	Total PMAI
KC-46A equivalents	163	205	368
Future Tanker	20	75	95
Total	**183**	**280**	**463**

Table 23 lists KC-46A tanker equivalents and a future tanker to support operations of U.S. air forces deployed to the Indo-Pacific and European conflicts. Wargame teams believed an unmanned or optionally manned future tanker could increase the Air Force's ability to conduct air refueling operations over large areas and in the low end of contested environments.

Future Forces to Sustain Strategic Deterrence and Support Homeland Defense

Consistent with the recommended force planning construct, additional aircraft inventory would be needed to deter potential attacks, including nuclear strikes, against the United States and to support homeland defense during great power conflict. Aircraft in Table 24 are based on the recommendations of subject matter experts who participated in CSBA's workshops and wargame. It assumes that approximately one squadron of future B-21s and another squadron of B-52Hs supported by dedicated tanker aircraft would provide a standoff and penetrating nuclear strike capability. Additional forces could be withheld or recalled from a theater of conflict if needed to further enhance strategic deterrence. Actual withholds for strategic deterrence in the event of a conventional conflict with a major nuclear power would be contingent on factors that are outside the scope of an unclassified report.

TABLE 24: FUTURE AIRCRAFT INVENTORY TO SUPPORT HOMELAND DEFENSE AND SUSTAIN STRATEGIC DETERRENCE DURING GREAT POWER CONFLICT

Aircraft	Homeland Defense	Strategic Deterrence	Total PMAI
B-21	0	14	14
B-52H	0	14	14
F-16	146	0	146
MM-UAS	30	0	30
KC-46A equivalents	45	60	105
Total	**221**	**88**	**309**

The F-16s and MM-UAS in Table 24 are teamed to counter cruise missile strikes and other air attacks on the U.S. homeland. These aircraft are placeholders to illustrate future forces that may be needed for these missions. Requirements could be much higher, contingent on the nature of emerging threats to the U.S. homeland.

Summarizing the Future Force

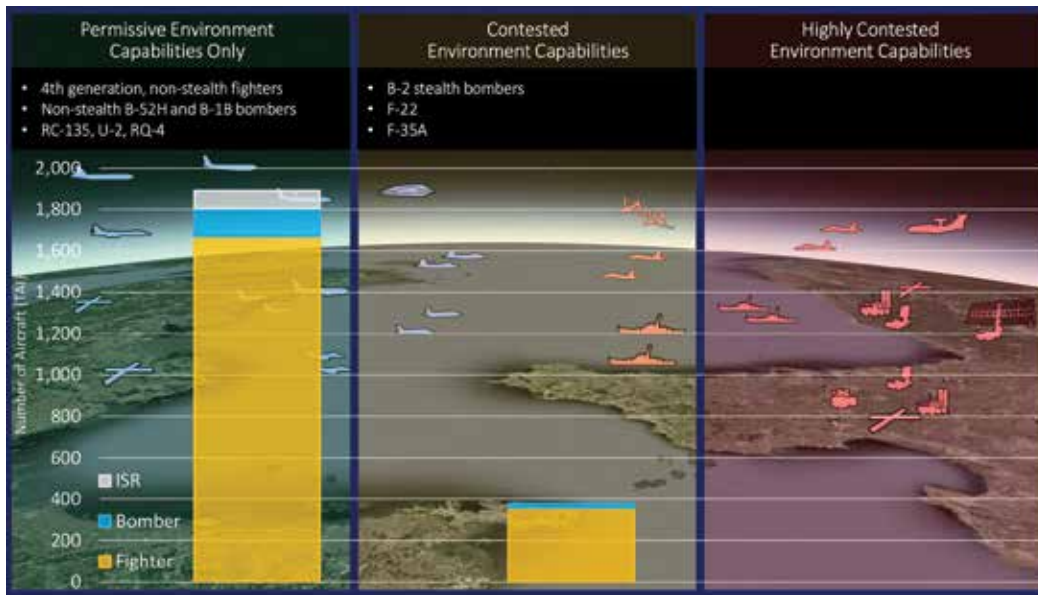
TABLE 25: TAI AND SQUADRON EQUIVALENTS IN THE FUTURE FORCE

	Aircraft	PMAI or TAI	Squadron Equivalents	TAI
Bombers	**B-2**	16 PMAI	1	20
	B-21	206 PMAI	19	288
	B-52H	44 PMAI	4	75
	Total	**266**	**24**	**383**
Fighters	**F-15E**	100 PMAI	5	159
	F-16	306 PMAI	15	572
	F-22A	137 PMAI	7	186
	F-35A	586 PMAI	28	908
	PCA/P-EA	200 PMAI	10	282
	Total	**1,329**	**65**	**2,107**
ISR, Light Strike	**MM-UAS**	214 PMAI	35	291
	MQ-X	50 PMAI	8	68
	Total	**264**	**43**	**359**
ISR and BMC2	**P-ISR**	116 PMAI	23	120
	RQ-4	15 PMAI	3	16
	RC-135	15 PMAI	3	22
	ABMS	16 PMAI	4	21
	Total	**162**	**33**	**179**
Refueling	**KC-46A equivalents and Future Tanker**	630 TAI	58	630
	Total	**630**	**58**	**630**

Table 25 converts PMAI aircraft from Tables 22, 23, and 24 into squadron equivalents and TAI using conversion factors provided by the Air Force.[257]

The future force would have a total of 266 PMAI bombers and 1,329 PMAI fighters including PCA/P-EA aircraft. This translates to 24 bomber and 65 fighter squadron equivalents that are fully resourced to support joint operations. Converted to TAI, the future force would have 383 bombers, assuming B-2 bombers remain in the inventory, and 2,107 fighters.[258] It should be noted that each ABMS listed in Table 25 is a system-of-systems and not a single aircraft, and tanker aircraft are a mix of KC-46A equivalents and a future unmanned tanker. The current KC-46A program will acquire a total of 179 aircraft. A follow-on tanker could be a manned, unmanned, or optionally manned aircraft. In either case, the air refueling aircraft needed to support the proposed force planning construct—630 TAI—is about 38 percent larger than the Air Force's current tanker force.

FIGURE 51: TODAY'S AIR FORCE AIRCRAFT INVENTORY



This mix of capabilities would be a major departure from the Air Force's current aircraft inventory. The preponderance of the Air Force's current combat, ISR, and BMC2 air forces cannot penetrate and persist in the contested and highly contested environments (see Figure 51). Maintaining this mix of forces would dramatically hinder the Air Force's ability to conduct

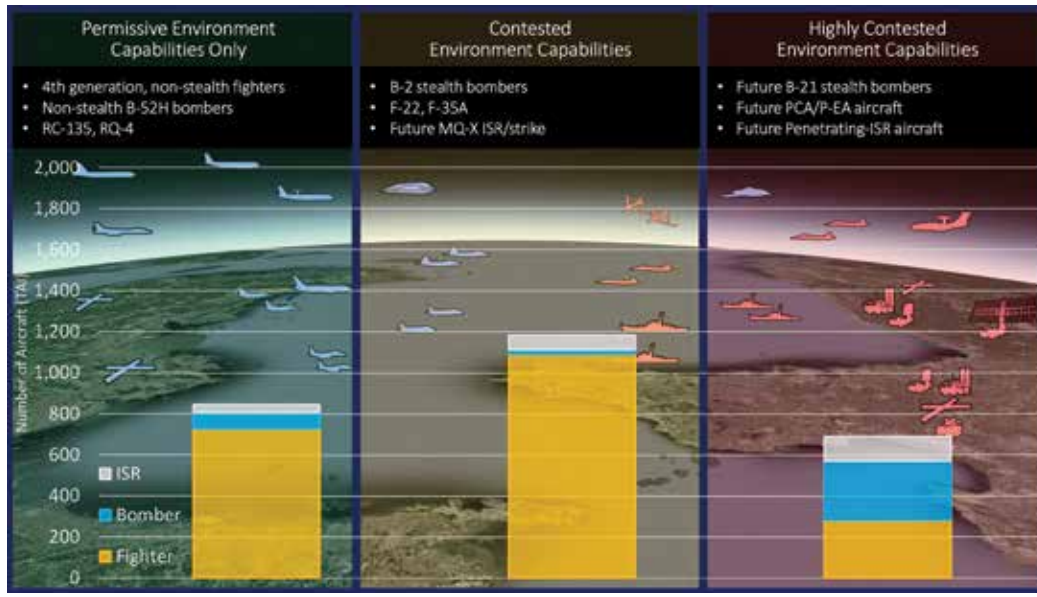
257 The number of PMAI and TAI for different platforms used to determine squadron equivalents in Table 25 were provided by the Air Force.

258 Similar to the MQ-9 Reaper RPA, future MM-UAS are not counted as fighters. CSBA assumed PMAI to TAI ratios for ABMS, MM-UAS, and P-ISR aircraft would be the same as ratios used today for the Air Force's E-3 AWACS, MQ-9 Reaper, and RQ-4 forces, respectively. Since the ABMS, P-ISR aircraft, and MM-UAS are concepts without fully defined requirements, their actual PMAI to TAI conversion ratios may be different.

future multi-domain operations against Chinese or Russian forces. Likewise, continuing to recapitalize and upgrade existing forces, as the United States has done since the end of the Cold War, instead of developing new, more capable weapons systems would further increase shortfalls in the Air Force's ability to support the *2018 National Defense Strategy*.

As illustrated in Figure 52, the future aircraft inventory would shift the Air Force's aircraft inventory toward a mix that is more survivable and has a better balance between fighters and bombers.

FIGURE 52: A FUTURE INVENTORY WITH GREATER SURVIVABILITY AND RANGE



This force structure should be complemented by the development of new operating concepts for global strike, close air support, counterair, electronic warfare, and other mission areas that employ a family of mutually supporting capabilities for high-end great power conflict.

Part 2: Recommendations for the Air Force's 2030 Aircraft Inventory

Part 2 of Chapter 7 provides specific recommendations for the Air Force's 2030 aircraft inventory. It begins by presenting a baseline inventory developed by CSBA using the Air Force's plans and programs projected to 2030. CSBA then makes recommendations for the 2030 inventory that are aligned with the recommended force planning construct and the future force summarized in Part 1 of Chapter 7.

Baseline 2030 Aircraft Inventory

TABLE 26: FY 2030 BASELINE PROJECTION FOR COMBAT, BMC2, AND ISR AIRCRAFT

Aircraft		FY19 TAI	CSBA FY30 TAI Projection	Comments
Bombers	B-52H	75	75	Air Force plans to retain at current TAI levels
	B-1B	62	42	Assumes B-1B retirements begin as B-21s join the force
	B-2	20	20	Will be retained through 2030
	B-21	0	38	Projection informed by limited information from DoD Selected Acquisition Reports
	Total	**157**	**175**	
Fighters	A-10	281	208	Air Force plans to restructure to 6 squadrons in 2021 and retain until early 2030s
	F-16	935	625	Assumes F-16s are divested as F-35As are procured
	F-15C/D	234	0	May retire in 2020s (*2018 Annual Aviation Inventory and Funding Plan)*
	F-15E	218	218	Assumes all are sustained and modernized
	F-22A	186	186	Assumes all are sustained and modernized
	F-35A	171	762	Assumes a planned procurement rate of 50 per year from 2019 through 2030
	Total	**2,025**	**1,999**	
ISR, Light Strike	MQ-9	252	252	Not counted as "fighters"
	Total	**252**	**252**	
BMC2	E-3	31	31	Will be replaced by ABMS
	E-8	16	0	Will be replaced by ABMS
	Total	**133**	**117**	
ISR	U-2	30	30	No plan to retire during this planning period
	RQ-4	34	34	
	RC-135	22	22	
	Total	**86**	**86**	

TABLE 27: FY 2030 BASELINE INVENTORY PROJECTION FOR AIR FORCE GLOBAL MOBILITY, CSAR, AND SPECIAL OPERATIONS AIRCRAFT

Aircraft		FY19 TAI	CSBA FY30 TAI Projection	Comments
Refueling	KC-135	398	341	Older KC-135s begin to retire as KC-46A enter force to sustain the overall fleet
	KC-46A	Initial deliveries	179	Assumes all 179 KC-46A are acquired by 2030
	KC-10	59	0	Expected to retire in 2020s, schedule may be stretched out due to refueling shortfall
	Total	**457+**	**520**	
Strategic Lift	C-17	222	222	
	C-5	52	52	
	Total	274	274	
Tactical Lift	C-130J	127	127	C-130Js will recapitalize all MC-130, HC-130, AC-130 variants
	C-130H	173	173	
	Total	**300**	**300**	
CSAR	HH-60	99	99	Being recapitalized
	HC-130	30	30	Being recapitalized
	Total	**129**	**129**	
Special Operations	AC-130	38	37	37 TAI by 2025 based on DoD's 30-year aviation plan
	MC-130	56	57	57 TAI by 2025 based on DoD's 30-year aviation plan
	EC-130J	7	7	
	CV-22	50	50	
	Total	**151**	**151**	

The projected inventory for FY 2030 in Tables 26 and 27 are based on unclassified information provided by the Air Force, congressional testimony, and other DoD sources. In several instances, CSBA made assumptions about projected acquisition timing, rates, and retirements of aircraft using best available sources. For instance, Table 26 assumes the Air Force will

procure F-35As at a rate of 50 per year, which is consistent with DoD's *2018 Annual Aviation Inventory and Funding Plan*.[259]

Recommendations for the 2030 Bomber Force

The size of the Air Force's bomber force is at a historic low, as is its ratio of long-range bombers to shorter-range fighter aircraft. The Air Force possessed more than 2,000 bombers at the end of the Eisenhower administration, one for every 2.5 fighters in its total inventory. By 1989, this force had fallen to 411 bombers, or one bomber for every ten Air Force fighters.[260] The Air Force's inventory now includes 157 bombers and approximately 13 times as many fighters as bombers. As addressed in Chapter 2, this shift toward shorter-range platforms was largely based on assumptions regarding the ability to use theater airbases located close to a regional adversary, the lack of threats to those bases, the potential to rapidly swing bombers between limited conflicts with lesser regional aggressors, and other factors. None of these planning assumptions remain valid for future high-intensity conflicts with China or Russia. To ensure it will have the capacity needed to conduct large-scale strike operations in contested and highly contested environments, the Air Force should rebalance its strike forces in favor of long-range, penetrating aircraft that can carry large payloads of weapons.

B-21 Raider. The Air Force should accelerate development, production, and testing of the B-21 so it reaches its initial operational capability threshold as soon as possible. Assuming annual B-21 production can ramp to a range between 10 and 20 aircraft per year by the late 2020s, a total of 55 TAI B-21s could be in the force by 2030.

B-2 Spirit. The Air Force should sustain and modernize as necessary its 20 TAI B-2A bombers until approximately 2040. Until the B-21 achieves operational capability, the B-2A will be the U.S. military's only aircraft capable of operating over very long ranges and penetrating deep into contested environments. It is also the best—and could, in some cases may be the only—means of delivering large, penetrating weapons capable of defeating very hard and deeply buried targets. It will also be the nation's only nuclear-capable stealth bomber until the B-21 is certified for the strategic deterrence mission. In light of these considerations, accelerating the retirement of the B-2A force is not recommended.

B-52H. The Air Force should sustain its current force of 75 TAI B-52H bombers well beyond 2030. The B-52H will be the backbone of the bomber leg of the nuclear triad until significant numbers of B-21 bombers join the operational force and are certified as nuclear capable. B-52Hs will be able to conduct standoff strikes into future contested environments using long-range, air-to-surface hypersonic weapons; air-to-air missiles, if teamed with penetrating

259 "Specifically, the Air Force plans to procure 250 F-35As from FY 2018 to FY 2022." DoD, *Annual Aviation Inventory and Funding Plan, Fiscal Years 2019–2048* (Washington, DC: DoD, March 2018), p. 7. Actual F-35A procurements requested in DoD's future budget submissions may be higher or lower.

260 See James C. Ruehrmund Jr. and Christopher J. Bowie, *Arsenal of Airpower: USAF Aircraft Inventory, 1950–2009* (Arlington, VA: Mitchell Institute, November 2010), available at http://secure.afa.org/Mitchell/Reports/MS_TAI_1110.pdf.

manned or unmanned aircraft that provide cues for very long-range intercepts; and maritime interdiction. Although the B-52H is one of the oldest combat aircraft in the Air Force's inventory, its airframe remains viable over the long-term. Continued modernization may be needed to ensure the B-52 remains part of the Air Force's family of capabilities for global strike well into the future, but major investments such as reengining should be weighed against opportunities to invest in newer and more capable platforms.

B-1B. The Air Force should sustain its B-1B force through most of the 2020s. While proven to be highly capable in operations since the end of the Cold War, the B-1B cannot penetrate contested or highly contested environments. And, unlike the B-52H, it does not presently have the capability to carry weapons externally. As the B-21 reaches its initial operational capability threshold, the Air Force should gradually retire its B-1B force at a rate that ensures it does not further increase the shortfall in its long-range strike capacity.

Table 28 summarizes a 2030 bomber inventory based on these recommendations.

TABLE 28: RECOMMENDATIONS FOR BOMBER FORCE TAI THROUGH 2030

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
B-21 (notional accelerated production rate)	0	0	0	0	0	1	5	10	15	25	40	55
B-1B (notional retirement schedule)	62	62	62	62	62	62	62	62	62	57	52	42
B-2	20	20	20	20	20	20	20	20	20	20	20	20
B-52H	75	75	75	75	75	75	75	75	75	75	75	75
Total	**157**	**157**	**157**	**157**	**157**	**158**	**162**	**167**	**172**	**177**	**187**	**192**

Recommendations for the 2030 Fighter Force

The Air Force's FY 2019 fighter force predominately consists of non-stealth aircraft that were originally designed and delivered in the 1990s or earlier. So-called 4th generation, non-stealth A-10, F-15C/D, F-15E, and F-16 block variants constitute about 97 percent of the Air Force's current PMAI fighter force.[261] Production of the 5th generation F-22A ceased at 187 aircraft, far short of the Air Force's original requirement of 750 aircraft. DoD's decision to terminate the program in 2009 was partially based on a belief that more were not needed, given a perceived lack of a threat to the U.S. military's ability to quickly achieve air dominance. As a consequence, the Air Force has major shortfalls in its ability to conduct counterair, CAS, electronic attack, and other combat missions in contested and highly contested environments. The following recommendations would help reduce these capability gaps.

261 "F-16 Fighting Falcon," factsheet, U.S. Air Force, September 23, 2015, available at http://www.af.mil/About-Us/Fact-Sheets/Display/Article/104505/f-16fighting-falcon/.

A-10 Thunderbolt II. The Air Force plans to retain six combat-coded A-10 squadrons until the early 2030s.[262] The Air Force should sustain this smaller force of 208 TAI A-10s as planned. Given that nearly all of its future precision-enabled combat aircraft will capable of providing close air support to friendly forces, the Air Force should not develop a future replacement for the A-10 that would be limited to operations in permissive environments.

F-16 Falcon. The majority of the F-16 fighters the Air Force is retiring are from squadrons that are converting to F-35As. Air Force F-16s can be aggregated into "lower block" variants and more capable "higher block" (Block 40/42 and Block 50/52) variants. The Air Force should retire its lower block F-16s first, retain and continue to upgrade higher block aircraft to maintain required force capacity, and fund a service life extension program to extend their service lives until they can be replaced. A significant number of F-16s (160 PMAI/300 TAI) were used by wargame teams to defend against Chinese and Russian air and missile attacks on U.S. airbases. The Air Force should also assess the feasibility of using F-35A fighters instead of F-16s for this mission in the future. The F-35A's sensor suite and information fusing capabilities could significantly contribute to defeating cruise missiles and other air and missile threats to U.S. bases and forces.

F-35A Lightning II. The Air Force's newest 5th generation fighter has an enhanced set of capabilities that will enable it to survive in future contested environments. Designed to replace the F-16 and A-10 force, the F-35A program has been beset by a number of well-known growing pains. However, it appears to have turned the corner. The latest LRIP F-35A unit purchase price was $89.2 million, and future procurements may reach $80 million per aircraft by 2020.[263] F-35As have deployed to the Indo-Pacific region and Europe, and they have supported combat operations. The Air Force is ramping up its annual procurement of F-35As with the latest software block (3F). In FY 2018, the Air Force accepted delivery of 44 F-35As. To accelerate fielding of the future force, the Air Force should increase its F-35A procurement to at least 70 per year as soon as possible. This could help reduce overlap with production of the B-21 and the development and procurement of other future manned and unmanned aircraft. The Air Force should also request multi-year procurement of the F-35A, which could save billions of dollars in program costs.[264]

262 DoD, *Annual Aviation Inventory and Funding Plan, Fiscal Years 2019-2048*, p. 7.

263 According to a statement by the F-35 Joint Program Office, "We are committed to reducing costs, and confident the final negotiated LRIP 12 aircraft unit prices will be less than LRIP 11, and enable us to deliver on our goal of an $80 million F-35A by 2020." Ben Werner, "Pentagon Awards $6 Billion Contract Modification to Keep F-35 Production Rolling," *USNI News,* November 15, 2018, available at https://news.usni.org/2018/11/14/pentagon-awards-6-billion-contract-modification-keep-f-35-production-rolling.

264 Based on a RAND Project Air Force study commissioned by DoD's F-35 Joint Program Office, multi-year procurement of F-35As in FY 2018–2020 had the potential to save "about $2.1 billion, or 4.9 percent of the cost of procuring these lots through annual contracting. . . . These savings are roughly comparable to those estimated for historical multiyear contracts for other fighter aircraft." James D. Powers et al., *F-35 Block Buy: An Estimate of Potential Savings* (Santa Monica, CA: RAND Corporation, 2018), p. xiii.

F-15E Strike Eagle. Produced between 1987 and 2004, Strike Eagles are the Air Force's newest F-15 fighter aircraft. The Air Force should sustain and modernize its F-15E force through 2030. F-15Es will need a service life extension program in the 2020s if they are to remain in the force past 2030.

F-15C/D Eagle. F-15C/D fighters were the nation's premier air superiority fighter until the F-22A reached its initial operational capability in December 2005. Due to DoD's decision to truncate F-22 procurement, F-15C/Ds have remained in the active force longer than originally planned. This has led to significant issues with the F-15C's sustainability.[265] Given the F-15C/D's limited remaining operational life, the Air Force should continue with its plan to retire its F-15C/D force in the 2020s. It should also develop and begin to field a family of capabilities as soon as possible that will provide the Joint Force with the degree of air superiority it will need to conduct operations in contested and highly contested airspace. In the interim, the Air Force may need to replace some of its retiring F-15C/Ds with modified F-35As to help fill the gap in air superiority capabilities until the PCA aircraft joins the future force.

F-15X. The Air Force could procure some number of F-15Xs in the 2020s to recapitalize its aging F-15C/Ds. Although F-15Xs are more capable than F-15C/Ds, they would not be able to operate in future contested and highly contested environments, and a program to buy these "new-old" aircraft could reduce resources needed to develop the future force. In other words, this option could possibly maintain capacity for counterair operations in the permissive environment at the expense of capabilities needed for future operations in contested and highly contested environments.

F-22A Raptor. The Air Force should sustain and continue to modernize its F-22A force at least through FY 2030. The F-22A will remain DoD's most effective counterair fighter until future penetrating counterair aircraft join the force.

Penetrating Counter Air/Penetrating Electronic Attack. Based on unclassified information, the PCA/P-EA should be an advanced aircraft capable of operating freely in contested and highly contested environments from significant ranges to perform timely air-to-air and SEAD/DEAD operations. As part of a family of capabilities for counterair that includes other platforms, sensors, and air-to-air and SEAD/DEAD weapons, the PCA/P-EA aircraft would help degrade area-denial threats and reduce risk for penetrating platforms and weapons. The Air Force should develop and procure a PCA/P-EA to conduct counterair, electronic attack, and other missions to defeat Russian and Chinese airborne and surface access denial systems. A PCA/P-EA aircraft should also have enough range, possibly 1,500 nm or more, to allow integration of its operations with other long-range penetrators. Similar to the B-21 program, maximizing the use of mature technologies—and possibly components and mission systems developed for other advanced platforms—could reduce the time and cost of fielding

265 Jeremiah Gertler, "Defense's 30-Year Aircraft Plan Reveals New Details," *In Focus*, Congressional Research Service, October 9, 2018, available at https://fas.org/sgp/crs/weapons/IF10999.pdf.

a multi-mission PCA/P-EA aircraft. This capability is needed now, and therefore its development should be a top priority.

Table 29 summarizes a fighter force inventory to 2030 based on these recommendations.

TABLE 29: RECOMMENDATIONS FOR FIGHTER FORCE TAI THROUGH FY 2030

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
A-10	281	281	251	221	208	208	208	208	208	208	208	208
F-16 (illustrative draw-down)	935	915	895	875	845	815	785	755	715	685	655	625
F-15C/D (illustrative draw-down)	234	200	170	140	110	80	50	25	0	0	0	0
F-15E	218	218	218	218	218	218	218	218	218	218	218	218
F-22A	186	186	186	186	186	186	186	186	186	186	186	186
F-35A	171	221	281	351	421	491	561	631	701	711	841	911
PCA/P-EA (notional ramp)	0	0	0	0	0	2	4	8	16	24	36	50
Total	**2,025**	**2,021**	**2,001**	**1,991**	**1,998**	**2,000**	**2,012**	**2,031**	**2,044**	**2,092**	**2,144**	**2,198**

Recommendations for the Air Force's 2030 ISR/Light Strike Inventory

The Air Force's inventory of unmanned systems experienced tremendous growth to meet operational requirements following the terrorist attacks on the U.S. homeland in September 2001. The following recommendations are intended to shift the Air Force's ISR/light strike force toward a future mix for operations in contested environments while sustaining the capacity needed to support near-term operational demands.

MQ-9. The Air Force has divested all of its MQ-1 Predator aircraft and increased the size of its MQ-9 force to support 60 combat air patrols. The MQ-9 force should be sustained through 2030 to help meet continued high operational demand for airborne ISR assets. The Air Force should also assess the potential for modified MQ-9s to support homeland defense and some theater airbase defense operating concepts similar to the airborne weapons layer concept developed during CSBA's workshops and wargame.

Multi-Mission UAS. This report uses the term "Multi-Mission UAS" as a proxy for a follow-on to DoD's current RPA that can perform a variety of combat and combat support missions in permissive environments and possibly at the low end of contested environments. A force of MM-UAS could support communication networks that extend into contested environments, and conduct air-to-surface strike, ISR, electronic warfare, and airbase defense if appropriately equipped. If based on existing technologies or an upgraded variant of a current UAS, an MM-UAS could be quickly acquired.

Future MQ-X. According to DoD's *2018 Annual Aircraft Inventory and Funding Plan,* "The Air Force began early Joint Capabilities Integration and Development work to develop an

Analysis of Alternatives for the next generation ISR-Strike" unmanned aircraft.[266] Workshop and wargame teams identified a pressing need for a future penetrating UCAS that could conduct strike, electronic attack, counterair, and other combat missions as part of a family of systems or teamed with manned aircraft. Unmanned system technologies are sufficiently mature to support the development and fielding of an air- refuellable multi-mission UCAV in the near-term. The Air Force should build on previous UCAV developmental programs to initiate the development of an MQ-X UCAV that can penetrate and persist in contested environments as soon as possible.[267]

TABLE 30: RECOMMENDATIONS FOR ISR/LIGHT STRIKE TAI THROUGH FY 2030

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
MQ-9 / MM-UAS	252	252	252	252	252	252	252	252	252	252	252	252
MQ-X (illustrative procurement ramp)	0	0	0	0	0	0	0	1	5	10	20	40
Total	**252**	**252**	**252**	**252**	**252**	**252**	**252**	**253**	**257**	**262**	**272**	**292**

Recommendation for Future Light Attack Aircraft

Future Light Attack Aircraft for OCO and homeland defense. New low-end, non-developmental aircraft that cost less to procure and operate relative to 4th and 5th generation platforms could help meet current operational needs for light strike and manned ISR in permissive environments. The need for new light attack aircraft for the Air Force has been a controversial issue.[268] Supporters have argued that light attack aircraft could help increase the readiness of 5th and future 6th generation combat air forces and their aircrews and maintainers for high-intensity warfare. Detractors have cited the risk that a light attack program could siphon resources needed to transition the Air Force to a future force that is better capable of supporting the *2018 National Defense Strategy*. Participants in CSBA's workshops and wargame generally agreed light attack aircraft had value as additive capabilities, not as replacements for high-end force structure. Furthermore, the "light attack" concept should include unmanned as well as manned aircraft.

In light of these observations, the Air Force should procure a light attack aircraft that could reduce the cost of supporting current overseas contingency operations. Other missions could include defensive counterair, maritime patrol, and counter-narcotics. Some missions might require a light attack aircraft to be equipped with a datalink, an air-to-air radar, a defensive suite, and appropriate weapons. Mission systems could quickly increase the unit cost of light attack aircraft. The cost of acquiring, equipping, and maintaining new light attack aircraft

266 DoD, *Annual Aviation Inventory and Funding Plan, Fiscal Years 2019–2048*, p. 34.

267 For instance, the Air Force could leverage technologies developed by the Navy's Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) developmental program and the follow-on MQ-25 program.

268 Many of the pros and cons of light attack aircraft are summarized in Stephen Losey, "A Light Attack Aircraft Fleet: Could It Change the Fight or Put Lives at Risk?" *Air Force Times,* February 20, 2018, available at https://www.airforcetimes.com/news/your-air-force/2018/02/20/a-light-attack-aircraft-fleet-could-it-change-the-fight-or-put-lives-at-risk/.

should be balanced against resources needed to transition the Air Force's aircraft inventory to a force that is better capable of conducting operations in highly contested environments. In addition to current non-developmental candidate aircraft, the Air Force should assess the potential to modify its future T-X training aircraft to conduct light attack operations in permissive environments and support homeland defense.

Recommendations for the Air Force's 2030 BMC2 Inventory

Developing a multi-domain BMC2 force capable of supporting operations in future contested environments should be one of the Air Force's highest priorities. Air Force BMC2 aircraft are based on 1950s-era airframes that are increasingly difficult to sustain. This inventory includes eleven E-3B and three E-3C AWACS that are upgraded versions of E-3As procured in the late 1970s and early 1980s. The Air Force also has E-3G AWACS that have new mission system computers, displays, improved software for data fusion, and other upgrades. To maintain its BMC2 capacity in the near-term, the Air Force is upgrading seven E-3B/Cs that it planned to retire to an E-3G configuration. This will help sustain its BMC2 capacity in the near term as it develops an Advanced Battle Management System that will operate in permissive, contested, and highly contested environments. The ABMS will support the GMTI mission, allowing the Air Force to retire its E-8 JSTARS.

E-3 AWACS. The Air Force should retain, sustain, and modernize the E-3 AWACS force through 2030 as planned. It should also complete an analysis of alternatives for the Advanced Battle Management System as quickly as possible and develop and field a material solution before the E-3 reaches its projected end of service life in the mid-2030s.[269]

E-8C JSTARS. Although the JSTARS is useful in permissive operating conditions, it cannot survive in contested environments, and it cannot be significantly modified to increase its survivability.[270] Recognizing these limitations, the 2019 NDAA rescinded funds to recapitalize the JSTARS fleet.[271] The Air Force should retire its JSTARS force by the mid-2020s at a pace that ensures it will not cause a gap in needed BMC2 and GMTI capacity.

269 Quincy Boles, "ACC ABMS AoA Information to Industry," PowerPoint briefing, U.S. Air Force, presented on August 2, 2018.

270 "The recapitalization of the current JSTARS platform is not viable in future contested environments, putting the Battle Management Command and Control and Ground Moving Target Indicator missions at risk in a peer engagement." Lieutenant General Jerry Harris Jr., Air Force Deputy Chief of Staff for Strategic Plans and Requirements, and Susan Thornton, Director of Information Dominance Programs Office of the Assistant Secretary of the Air Force for Acquisition, "Fiscal Year 2019 Budget Request on Air Force Airborne Intelligence, Surveillance and Reconnaissance (ISR) Programs," statement to the House Armed Services Committee, Subcommittee on Tactical Air and Land Forces, March 15, 2018, pp. 2–3, available at https://docs.house.gov/meetings/AS/AS25/20180315/107979/HHRG-115-AS25-Wstate-HarrisJ-20180315.pdf.

271 See Mac Thornberry and Adam Smith, "H.R. 5515: National Defense Authorization Act for Fiscal Year 2019," Statement of Administration Policy, May 22, 2018, p. 3, available at https://www.whitehouse.gov/wp-content/uploads/2018/05/saphr5515r_20180522.pdf; and Mark Cancian, "Congress Traded Operations & Maintenance for Modernization in 19 Appropriations," *Breaking Defense*, October 11, 2018, available at https://breakingdefense.com/2018/10/congress-traded-om-for-rdte-in-19-approps-bill/.

Advanced Battle Management System. The Air Force should develop an ABMS that provides the Joint Force with BMC2 and GMTI in all threat environments. Similar to Air Force capability development initiatives for counterair and electronic warfare, the ABMS should be a multi-domain system-of-systems, not an aircraft recapitalization program. The initiative should pursue innovative concepts, including manned-unmanned teaming, and new technologies to fuse information from sensors operating in all domains. The Air Force should begin fielding the ABMS in 2030 or shortly thereafter if possible.

TABLE 31: RECOMMENDATIONS FOR BMC2 TAI THROUGH FY 2030

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
E-3	31	31	31	31	31	31	31	31	31	31	31	31
E-8C	16	16	16	14	12	10	8	4	0	0	0	0
ABMS	Begin acquisition in 2030 or shortly thereafter											
Total	**47**	**47**	**47**	**46**	**43**	**41**	**39**	**35**	**31**	**31**	**31**	**31**

Recommendations for the Air Force's 2030 ISR Inventory

The Air Force's non-stealth RQ-4 Global Hawk and U-2 are in high demand in multiple theaters. The RC-135 Rivet Joint strategic reconnaissance aircraft is an extensively modified capability that first entered the force in the 1960s. Similar to the E-8 JSTARS, the RC-135 is a permissive environment capability. The following recommendations are intended to shift the Air Force's ISR force toward a future mix for operations in contested environments while sustaining the capacity needed to support near-term operational demands.

RQ-4 Global Hawk and U-2. The Air Force should sustain and modernize as necessary its RQ-4 and U-2 inventories through 2030. Earlier retirements of either aircraft would increase DoD's known shortfall in strategic surveillance capacity and not take advantage of their remaining service lives.

RC-135. The Air Force should retain, sustain, and modernize as needed the RC-135 force through at least 2030. A 2008 RC-135 Air Force Fleet Viability Board (FVB) determined that "despite the fleet average airframe age of 44 years and total of 38,000 flight hours at of the end of FY 2007, the RC-135 should be able to continue to meet the Combatant Commanders' needs through at least 2040."[272]

Future penetrating ISR. Persistent, penetrating airborne ISR will be critical to the air interdiction of highly mobile armored vehicles and other land forces invading a NATO ally; likewise, they will be instrumental in finding, fixing, tracking, and providing shooters with cues to attack mobile SAMs, missile launchers, and other high-end threats. Fielding one or

272 The same Congressional Research Service (CRS) report quoted here identified concerns over the U.S. C2ISR industrial base's ability to sustain this fleet: "Another potential oversight issue is the ability of the nation's industrial base to sustain the legacy C2ISR aircraft force. A potential problem with sustaining a fleet of aircraft of their age is that the industrial base that developed and produced these aircraft may no longer possess the capability to manufacture and supply parts in the necessary quantities to affordably keep these aircraft flying." Jeffrey Nelson, *U.S. Command and Control and Intelligence, Surveillance, and Reconnaissance Aircraft* (Washington, DC: CRS, July 15, 2015), pp. 26–34, 49.

more unmanned P-ISR variants should be one of the Air Force's highest priority for its future global awareness force.

TABLE 32: RECOMMENDATIONS FOR ISR TAI THROUGH FY 2030

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
RQ-4	34	34	34	34	34	34	34	34	34	34	34	34
U-2	30	30	30	30	30	30	30	30	30	30	30	30
RC-135	22	22	22	22	22	22	22	22	22	22	22	22
Total	**86**	**86**	**86**	**86**	**86**	**86**	**86**	**86**	**86**	**86**	**86**	**86**

Recommendations for the Air Force's 2030 Air Refueling Force

The size of the Air Force's tanker force is at a historic low, and its average age of about 53 years is at a historic high. The ability to conduct aerial refueling in permissive environments and at the low end of contested environments will be essential to future Air Force and Navy multi-domain operations. This will require the Air Force to develop new operating concepts and at least one new, purpose-built tanker in addition to the KC-46A. This new tanker should have the ability to offload fuel to multiple platforms with and without the use of a boom. Similar to other elements of the future force, Air Force tankers should be capable of operating from a more dispersed basing posture compared today's KC-135 and KC-10 force. The most significant challenge, however, may be supporting highly distributed joint air operations in Europe and over the vast distances of the Indo-Pacific theater during great power conflict. A shortfall in the number of booms the Air Force can generate to support these operations may be more significant than fuel offload capacity shortfalls. The following recommendations address these challenges.

KC-135. The Air Force should coordinate its retirement of the KC-135 force with the procurement of replacement aircraft to ensure the shortfall in air refueling capacity does not increase. The Air Force should also sustain and modernize the KC-135R/T fleet as necessary until it is retired to ensure it remains capable of meeting the Joint Force's air refueling requirements.

KC-10. The Air Force had planned to begin the retirement of its KC-10s in 2019 and complete it by 2024. To avoid increasing its current gap in air refueling capacity, the Air Force should delay the KC-10's retirement by two or more years to ensure a sufficient number of operational KC-46A tankers have joined the force.

KC-46A. The Air Force should procure the KC-46A through 2027 as planned to replace its aging KC-135R/T and KC-10. It should also plan to upgrade KC-46As to serve as a communications and situational awareness nodes to support multi-domain operations. Upgrades should also provide it with some countermeasures against area-denial threats.[273]

273 Air Mobility Command priorities for its mobility aircraft include improving their on-board situational awareness, off-board situational awareness, and ability to defend against threats. "AMC Capability Gaps," briefing slides, Headquarters, Air Mobility Command, provided to CSBA on October 13, 2018.

Future air refueling tanker/follow-on to the KC-46A. Aerial refueling in permissive environments and in the low end of the contested environment will be essential to future joint operations. CSBA's workshops and wargame teams considered a future unmanned tanker as a leading concept for this mission. Other tanker alternatives considered included a small, unmanned tanker, an optionally manned aircraft that could significantly increase the number of expeditionary airfields the future tanker force could operate from during great power conflict, and a "lightweight," highly efficient platform that would maximize its fuel offload potential. The Air Force should move forward with an Analysis of Alternatives and the development of an Initial Capabilities Document (ICD) for a tanker that could enter produc- tion in time to prevent a gap in its air refueling force recapitalization after the procurement of 179 KC-46As is completed in the late 2020s. The Analysis of Alternatives should assess concepts that are consistent with candidate future air refueling aircraft explained in greater detail in Chapter 6.

TABLE 33: RECOMMENDATIONS FOR TANKER TAI THROUGH FY 2030

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
KC-135	398	398	398	398	393	388	383	377	362	352	342	341
KC-10	59	59	49	39	29	19	9	0	0	0	0	0
KC-46A	Initial deliveries	38	53	68	83	98	113	128	143	158	173	179
Future Tanker	Develop and begin low-rate production before 2030 to avoid gap in tanker force recapitalization											
Total	**457+**	**495**	**500**	**505**	**505**	**505**	**505**	**505**	**505**	**510**	**515**	**520+**

Recommendations for the 2030 Strategic and Tactical Airlift Force

C-17A and C-5M. The strategic airlift force may be the Air Force's healthiest force. The Service procured its final C-17A in September 2013 and has upgraded its C-5s. The Air Force should sustain this force through 2030. Changes to joint operating concepts and the force structures of other Services—particularly the Army—could change future requirements for strategic lift significantly. These changes should be assessed by a comprehensive DoD Mobility Capabilities and Requirements Study.

Civil Reserve Air Fleet. The CRAF consists of aircraft pledged by airlines and other civil air carriers to provide cargo and passenger airlift to DoD in emergencies. By surging aircraft for these missions, the CRAF improves the U.S. military's ability to respond to crises and potentially free up military platforms for other critical missions. DoD should maintain the CRAF at planned levels and assess policies, incentives, and self-defense capabilities that could improve their ability to operate in lightly contested areas.

Tactical airlift. The Air Force should sustain and modernize its theater airlift forces as necessary through 2030. Similar to strategic airlift, future requirements for theater airlift will be dependent on multiple factors including emerging joint doctrine and the future composition of the Army and other joint forces. Assessing these unknowns are outside the scope of this assessment. The Air Force should also assess its future requirements for dedicated tactical

airlift to support its adaptive basing concept for conducting dispersed operations against adversaries with A2/AD complexes.

TABLE 34: RECOMMENDATIONS FOR STRATEGIC AND TACTICAL AIRLIFT TAI

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
C-17	222	222	222	222	222	222	222	222	222	222	222	222
C-5M	52	52	52	52	52	52	52	52	52	52	52	52
C-X	0	0	0	0	0	0	0	0	0	0	0	0
CRAF	No proposed changes in capacity											
Strategic Lift Total	**274**	**274**	**274**	**274**	**274**	**274**	**274**	**274**	**274**	**274**	**274**	**274**
C-130J	127	127	127	127	127	127	127	127	127	127	127	127
C-130H	173	173	173	173	173	173	173	173	173	173	173	173
Tactical Lift Total	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**	**300**

Recommendations for the Air Force's Combat Search and Rescue, Special Operations, and Training Aircraft Inventories

The Air Force should retain some number of legacy HH-60G aircraft in the short term and acquire the Combat Rescue Helicopter to ensure it will have sufficient capacity to support current and future conflicts. The Air Force should also develop a future CSAR force to conduct sustained operations in all future operational environments. Future CSAR systems should have improved sensor capability and the ability to connect and share information. Unmanned, autonomous technologies and manned-unmanned teaming would improve CSAR operational effectiveness in contested areas. The Air Force should continue its planned recapi- talization and modernization of its special operations and training aircraft inventories.

Other Recommendations

Future airbase defense. It is highly likely that theater bases critical to future U.S. air operations will be subject to kinetic and non-kinetic attacks during a major conflict with China or Russia. Current DoD guidance on the Services' responsibilities to organize, train, and equip forces for airbase defense is ambiguous. Given the magnitude of the threat, the Air Force should assume greater responsibility for defending its theater airbases. Specifically, the Air Force should be responsible for most future air and space sensors to detect and track salvos of ballistic missiles, cruise missiles, hypersonic glide vehicles, and other emerging missile threats. In addition, the Air Force should be responsible for passive air and missile defenses and active defenses against Group 1 and Group 2 UAS for airbases as needed.[274] It should also share responsibilities with the Army and other U.S. force providers for active

274 Group 1 and 2 unmanned aircraft are small aircraft that weigh less than 55 lb and fly below 3,500 ft above ground level (AGL) at airspeeds of less than 250 knots. Group 3 UAS have a maximum gross weight of less than 1,320 lb and operate below 18,000 ft mean sea level (MSL) at airspeeds of less than 250 knots. Group 4 UAS have a maximum gross weight of more than 1,320 lb and operate below 18,000 ft MSL at any airspeed. Group 5 UAS have a maximum gross weight of more than 1,320 lb and operate above 18,000 ft MSL at any airspeed. DoD, *FY2009–2034 Unmanned Systems Integrated Roadmap* (Washington, DC: DoD, April 6 2009), pp. 96–97, available at https://www.globalsecurity.org/intell/library/reports/2009/dod-unmanned-systems-roadmap_2009-2034.pdf.

airbase defenses against Group 3 and higher UAS, ballistic missiles, and cruise missiles. The Air Force may need additional funding and end strength for these increased roles-and-missions responsibilities.

U.S. munitions and missile industrial base. DoD inventories of preferred munitions have long lacked the resiliency needed to support high-intensity conflicts of long duration. There is a common misperception that the U.S. industrial base has the ability to quickly surge its production of air-to-air, surface-to-air, and air-to-surface munitions during a major crisis. In reality, this surge capacity is almost non-existent, especially at the sub-contractor level where many weapon components are manufactured. Increases in the size of the Air Force's aircraft inventory recommended by this report should be accompanied by increased investments in the weapons they could expend in times of crisis. Absent these investments, current munitions shortfalls would persist or even grow, eroding the Air Force's future ability to perform its mission.

Opportunities for reduced Air Force operation and sustainment costs. As described in Chapter 1, there has been a significant growth in Air Force O&M expenditures, which reached a historic high of $63.7 billion in FY 2011 in constant year 2019 dollars. Part of this O&M growth has been the result of increased costs to operate and support an aging force. Retiring legacy aircraft such as F-15C/D fighters and E-8 JSTARS that are increasingly expensive to maintain and would require expensive life extension programs to keep in the force could help free resources needed for aircraft modernization and recapitalization programs. Maintaining a balanced high-low force mix of manned and unmanned systems in the near term and midterm as summarized earlier in this chapter could also reduce Air Force O&S expenditures. Finally, assessments of alternatives for future weapons systems should address their potential to reduce the Air Force's O&S costs as they mature, as well as the cost to develop and procure them.

Part 3: Illustrating Strategic Choices to Build the Future Force

The final part of Chapter 7 summarizes insights from a 2018 Strategic Choices Exercise that assessed the emerging operating environment, potential capability tradeoffs, and new investments that could place the Air Force on the glidepath toward developing the future force recommended in previous chapters. The exercise was designed to accomplish two objectives: identify major strategic choices facing the Air Force as it develops a future force that will be more lethal, ready, and capable of defeating great power conflict; and assess how different Air Force budget profiles over the next two FYDPs could affect these choices.

Overview of Strategic Choices Exercises

Strategic Choices Exercises provide a framework for national security strategists, defense planners, operational experts, and budgeteers to assess alternative force structures for a military service or a joint military force. CSBA has led multiple Strategic Choices Exercises to

evaluate alternative operating concepts and force structures to support national security strategies. Exercise participants first evaluate trends that should influence a military organization's future strategic priorities and then, using CSBA's Strategic Choices Tool, identify how its plans and programs could be reshaped to achieve those priorities.[275] The Strategic Choices Tool includes a database of forces, capabilities, and potential acquisition programs that players can choose to invest in or divest from over a future ten-year planning period.[276]

Experts from a range of defense planning, technological, and operational backgrounds participated in a 2018 Strategic Choices Exercise to develop alternatives to the Air Force's planned aircraft inventory and modernization programs over a ten-year period (2020–2029).[277] Four teams were given the Air Force's planned 2019–2029 force structure and modernization program baseline as a common starting point. Teams were tasked to retain or modify this baseline to address their strategic priorities, remedy Air Force capability and capacity shortfalls, and exploit promising emerging technologies. Each team was provided with a different ten-year funding profile to create a basis for comparing the sensitivity of their choices to resource levels. One team was given the Air Force's projected 2020–2029 budget profile adjusted for inflation; a second team was given the same profile minus $4 billion per year; a third team was given an increase of $4 billion per year; and a fourth team used the baseline budget plus an $8 billion increase per year (see Table 35).

TABLE 35: FOUR TEAMS, FOUR DIFFERENT TEN-YEAR BUDGET PROFILES

	FY 2020–2029 Budget Profiles
Team "Arnold"	**-$4 billion per year** for a $40 billion reduction below baseline budget over ten years
Team "Mitchell"	**Baseline budget,** any additional procurements must be offset by equivalent cost cuts
Team "LeMay"	**+$4 billion per year** for a $40 billion increase over baseline over ten years
Team "Olds"	**+$8 billion per year** for an $80 billion increase over baseline over ten years

275 Teams treat a Service's existing modernization plan as a baseline and modify it based on their individual rebalancing strategies. They do not build a new budget from the bottom up.

276 For more information on CSBA's Strategic Choices Tool, see Jacob Cohn and Katherine Blakely, "A Powerful Tool for Defense Strategy and Budget Planning," factsheet, Center for Strategic and Budgetary Assessments, available at https://csbaonline.org/uploads/documents/CSBA__Strategic_Choices_Handout.pdf. For another example of a Strategic Choices Exercise involving U.S. think tanks in advance of the 2016 U.S. Presidential Election, see Jacob Cohn, Ryan Boone, and Thomas G. Mahnken, *How Much Is Enough? Alternative Defense Strategies* (Washington, DC: Center for Strategic and Budgetary Assessments, 2016).

277 Team rebalancing activities are broken into two 5-year moves. While exercises could have one or two moves of any length, most exercises are effectively two FYDPs out. Framed this way, it is often easier for participants to visualize the potential duration associated with development programs and force generation. Multiple moves taken in this manner also stresses that force planning often incurs prerequisites (e.g., to stand up X force structure by 20YY, we need to invest in Z capability now and begin associated training and construction activities).

Strategic Choices Exercise Insights on the Air Force's Future Aircraft Inventory

While the Strategic Choices Exercise teams faced significantly different fiscal constraints, they all coalesced around three key issues:

- How quickly could the Air Force transition from its current force structure to one that is better capable of deterring and defeating great power aggression?
- To what extent should the Air Force invest in capabilities for non-traditional missions such as airbase defense?
- How should the Air Force balance investments in next-generation aircraft with critical enabling capabilities such as advanced munitions, penetrating ISR systems, and secure datalinks?

Transitioning the force. None of the teams considered it possible to create, *by 2030*, a force that would have a balanced mix of capabilities and the capacity to defeat major acts of Chinese and Russian aggression at low to moderate levels of risk. Part of their reasoning was that the national defense innovation base would be unable to develop and produce, at high enough rates, multiple new advanced aircraft and munitions such as hypersonic weapons and survivable stand-in attack munitions.[278] All four teams were, however, willing to accept short-term risk by retiring some legacy F-15C/D, F-16, and A-10 fighters earlier than planned to accelerate this transition. Teams posited that these platforms would be of limited utility during operations in future contested or highly contested environments.

Airbase defense, resiliency, and posture. The threat to airbases was deemed so significant that all teams invested in airbase passive hardening measures, additional dispersal airfields in the Indo-Pacific and Europe, and airborne airbase defenses consisting of legacy manned aircraft and UAS armed with air-to-air interceptors or directed energy weapons. Although all four teams recognized the critical nature of defending airbases against Chinese and Russian salvos, the two teams with budget profiles at or below the projected baseline assessed that the Air Force could not simultaneously begin to transition its aircraft inventory for great power competition *and* assume increased responsibility for defending its bases against air and missile attacks. If the Army could not provide needed airbase defenses, these teams thought the Air Force could, so long as it was provided with additional budget and end strength. The two teams with an increased budget allocated some of their budget plus-ups to procure ground-based air and missiles defenses, including high-energy lasers and high-power microwave directed energy weapons.

This emphasis on improving theater airbase resiliency was reflected in the teams' overseas posture realignments. Three teams elected to close bases in the United States, and two opted to reduce basing in the U.S. Central Command's area of responsibility in order to permanently

278 The national defense innovation base encompasses both the capacity of the defense industrial base to produce military capabilities as well as the national ability to innovate and develop new capabilities.

station more Air Force aircraft in the Indo-Pacific region and Europe. These initiatives were intended to create regional postures that would be more capable of supporting long-term U.S. great power competition objectives and deterring Chinese and Russian aggression. Moreover, stationing additional air forces in Europe and the Indo-Pacific region would reduce the time and resources, including strategic lift and air refueling, needed for the U.S. military to respond to crises in areas that may be subject to great power aggression.

Enabling capabilities including advanced munitions. While all teams agreed the Air Force's baseline aircraft inventory lacked the capacity and the right mix of capabilities for great power conflict, they acknowledged that procuring new aircraft alone would not be enough to support the *2018 National Defense Strategy*. The Air Force should balance its future investments in new force structure with investments to create larger stockpiles of advanced munitions pre-positioned in the Pacific and Europe, secure datalinks suitable for multi-domain operations in communications degraded areas, and other enabling capabilities. For instance, given the growing threat to U.S. theater airbases, the Air Force and other services should operate their aircraft from more dispersed postures in Europe and the Indo-Pacific region. To maintain combat efficacy during a conflict, these dispersed forces must be able to coordinate the effects they can create in time and space. This will require secure and resilient datalinks to support Air Force operations on the ground, in the air, in space, and in cyberspace. Teams invested in airborne communications nodes, buried fiber optic cable, cyber teams, additional satellites, and other options to enhance the resiliency of networks connecting U.S. theater bases and dispersed operating locations.

Teams also acknowledged the importance of surging its air and space ISR forces to facilitate future joint operations. The ability to surge space assets to increase coverage over specific areas in Europe and the Pacific will be essential to large-scale engagements against Chinese or Russian forces. Investing in a number of smaller, less expensive satellites would provide a surge capability and help preserve on-orbit satellite fuel reserves.[279] It would also help create denser constellations that would degrade more gracefully as they are attacked by a great power aggressor.

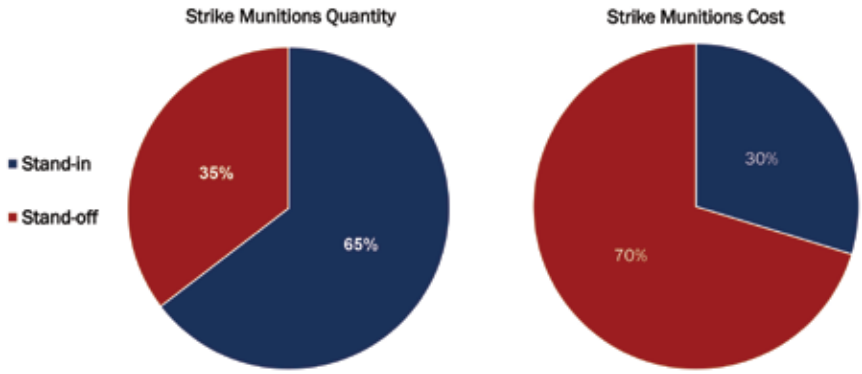
Finally, teams invested in a diverse mix of advanced stand-in and standoff munitions to rebalance and expand the U.S. munitions inventory from one optimized for short-range strikes in permissive environments toward one that would be better capable of supporting high-volume strikes into contested and highly contested environments.[280] Priorities included procuring a larger number of survivable stand-in munitions to support saturation strikes against Chinese and Russian IADS and weapons to attack large numbers of relocatable targets before they could move (see Figure 53). Teams did not invest in a large number of long-range, hypersonic weapons for these operations, since their high unit costs could reduce the number of weapons

279 Adjusting the orbit of a satellite expends its on-board fuel and decreases its operational life.

280 For more on future precision-guided munitions requirements, see Gunzinger and Clark, *Sustaining America's Precision Strike Advantage*.

the Air Force can afford. Their large size would also reduce the number that can be carried by strike aircraft in a single sortie compared to smaller stand-in weapons, and their lengthy flight times would reduce their utility against relocatable targets.

FIGURE 53: STRIKE MUNITIONS PROCUREMENT AND QUANTITY



Strategic Choices Exercise Investment Allocation

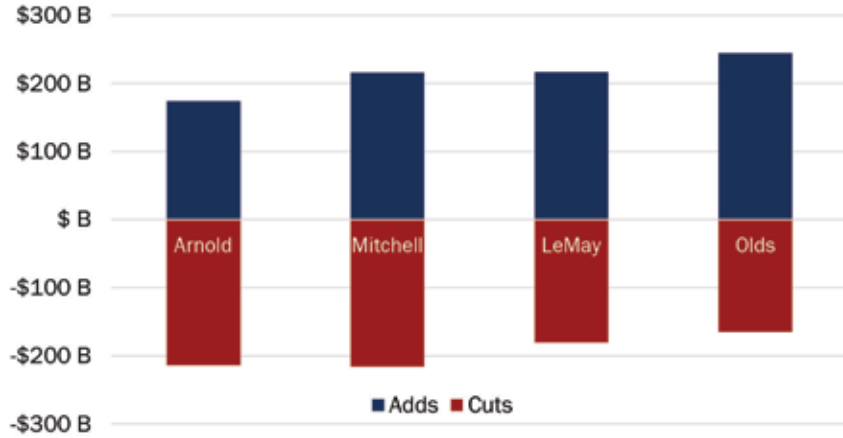
All four teams deviated substantially from the Air Force's program of record. Figure 54 illustrates the total costs of their new investments (blue columns) and total savings from their cuts (red columns). Teams reallocated an average of $194 billion toward their preferred capabilities and force capacity. Team Mitchell (baseline budget) did the greatest amount of program and force structure rebalancing, identifying roughly $216 billion in funding that it wanted to re-allocate toward capabilities and forces needed to operate in future contested environments.

To highlight the scale of the teams rebalancing decisions, CSBA grouped each team's selections into several categories (see Figure 55).[281] Over 80 percent of each team's investments corresponded to the three key rebalancing priorities: transitioning to the future force, creating a more resilient base posture, and investing in critical enabling capabilities and munitions.[282] Team LeMay was the most focused on these priorities, allocating 93 percent of its investments toward aircraft capable of penetrating highly contested environments, advanced munitions and other enablers, and airbase resiliency and defense.

281 The "other" category in Figure 55 represents investments to implement a Base Realignment and Closure process in the United States, procure low-cost turboprop fighters, upgrade F-16s, and develop a C-130 aircraft variant that can launch standoff weapons.

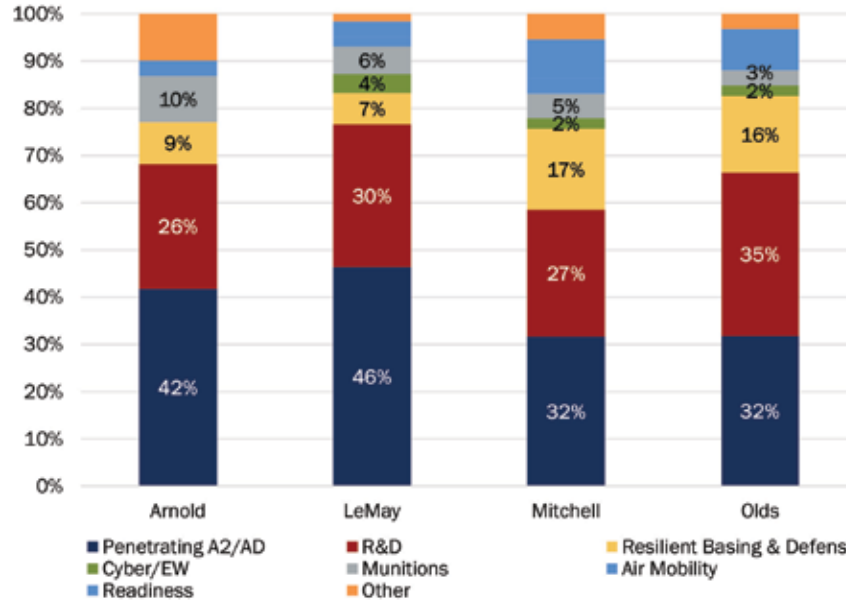
282 These priorities are covered by the listed percentages. For ease of readability, the other percentages are not presented.

FIGURE 54: OVERALL CUTS AND ADDS BY TEAM



Strategic Choices Exercise Team	Total FY 2020–2029 Budget Cut or Plus-Up	Total Cost of Team Adds	Total Savings from Team Cuts
Arnold	-$40 billion	$174 billion	$214 billion
Mitchell	Baseline	$216 billion	$216 billion
LeMay	+ $40 billion	$217 billion	$181 billion
Olds	+ $80 billion	$244 billion	$165 billion

FIGURE 55: INVESTMENT ALLOCATION BY TEAM



Arnold: Projected baseline - $4b per year	Mitchell: Projected baseline
LeMay: Projected baseline + $4b per year	Olds: Projected baseline + $8b per year

Time Needed to Transition to the Future Force

All four teams assessed that the Air Force would need significant increases to its annual budgets for an extended period of time in order to transition to a future force that will be better capable of deterring and defeating great power aggression. Table 36 summarizes major aircraft inventory adds and cuts by the teams.[283]

TABLE 36: FUTURE 2030 FORCE STRUCTURE HIGHLIGHTS IN TAI

	Baseline	Team Arnold (-$4B per year)	Team Mitchell (Baseline)	Team LeMay (+4B per year)	Team Olds (+$8B per year)	Chapter 7 2030 Recommendations
Bombers						
Non-Stealth	137	Baseline	-40 B-1B	-70 B-1B and B-52H	-60 B-1B	-20 B-1B
Stealth B-21	58	+17	+15	+12	+17	+17
Fighters						
4th Gen	1,006	-712 A-10, F-15, F-16	-491 A-10, F-15, F-16	-575 A-10, F-15, F-16	-412 A-10, F-15, F-16	Planned retirements
5th Gen	944	Baseline	+70	+90	+40	+149
6th Gen	0	+30	+30	+30	+60	+50
Airlift						
Tactical	270	-202 C-130H	-141 C-130H	Baseline	Baseline	Baseline
Strategic	274	-12 C-5	Baseline	Baseline	Baseline	Baseline
Refueling						
KC-135	319	Baseline	Baseline	Baseline	-10	Baseline
KC-46A	179	Baseline	+25	-25	+15	Baseline
Next-Gen	0	Develop next-gen tanker	Baseline	+20 Procure a more efficient tanker	+40 Procure a KC-46 follow-on tanker	Develop next-gen tanker
C2/ISR/Strike						
Legacy Manned	83	-30 U-2	-66 U-2, E-3, E-8	-76 U-2, E-3, E-8	-52 U-2, E-3, E-8	Planned retirements
Non-Stealth UAS	252	-120 MQ-9	-135 MQ-9, RQ-4	-35 RQ-4 / +30 MM-UAS	-240 MQ-9 / +60 MM-UAS	Baseline
Stealth UAS	0	+85 P-ISR, MQ-X	+60 MQ-X	+45 P-ISR, MQ-X	+35 P-ISR, MQ-X	+50 MQ-X
Total	3,769	-944	-673	-554	-507	+366

Table 36 illustrates that teams with the most constrained funding profiles (Team Arnold and Team Mitchell) were willing to make the largest reductions in the Air Force's near-term force capacity in order to fund capabilities needed in the future. These cuts included reductions to the Air Force's older C-130s, F-15C/Ds, and lower block F-16 fighters. All teams believed the need to accelerate B-21 procurement and begin a PCA/P-EA program was worth accepting risk in the near term by retiring less-capable legacy aircraft earlier than planned. Teams decided to

283 Future platforms such the PCA/P-EA and P-ISR aircraft could be manned or unmanned. For the purposes of Table 36, both were counted as unmanned aircraft.

procure a penetrating ISR platform and penetrating UCAS.[284] They also chose to accelerate the Air Force's procurement of the F-35A, with the notable exception of Team Arnold, which was tasked to absorb a $40 billion cut below the Air Force's baseline budget. In other words, the team's decision to forego procuring F-35A above baseline was driven by budget concerns.

Summary

Chapter 7 recommends a future force to support a force planning construct that would require the Air Force to size and shape its forces to defeat major acts of aggression by China and Russia, defend the U.S. homeland, and maintain strategic deterrence. These recommendations would shift the Air Force toward a mix of capabilities that would be more lethal, resilient, and able to operate in contested and highly contested environments. Most significantly, it would improve the Air Force's ability to operate from airfields that would be at less risk of high-intensity missile attacks and penetrate deeply into areas covered by Chinese or Russian anti-access and area-denial systems. In 2019, approximately 79 percent of the Air Force's total potential daily conventional munitions delivery capacity would be provided by fighters that have less than 1,000 nm of unrefueled combat radius. In the recommended future force, approximately 30 percent of munitions delivery potential would be provided by aircraft with an unrefueled combat radius greater than 1,000 nm. This metric understates the magnitude of the shift, however. In 2019, the Air Force has 16 PMAI B-2s that can strike at long range in contested environments. In contrast, the recommended future force would have 206 PMAI B-21s, 200 PCA/P-EA, and 16 B-2s. This force would substantially increase the number of targets the Air Force could strike nearly simultaneously over large areas covered by Chinese and Russian A2/AD threats.

The future force would also be more survivable and larger than the current force. Approximately 70 percent of the future fighter and bomber force would consist of 5th and 6th generation stealth aircraft, a four-fold increase from the 2019 inventory. The recommended force is also modestly larger, as would be expected by the shift toward preparing to deter and defeat great power aggression. The growth in the number of Air Force aircraft squadrons, however, is not as significant as the need to develop and procure a new generation of capabilities for operations in contested and highly contested environments.

Changes to the Air Force's 2030 aircraft inventory proposed in Chapter 7 would place it on a path toward the future force; it is not recommended that the Air Force attempt to *complete* its transition to a larger force better suited to the challenges of great power competition by 2030. This would require it to commit to procuring an inordinate number of weapons systems that are now in production, rather than more advanced weapons systems that could enter production in the late 2020s or in the 2030s. Based on CSBA's Strategic Choices Exercise, it would also be costly, likely prohibitively so. Moreover, future investments should balance inventory

284 The fourth team believed that the combination of a new PCA platform and another unmanned penetrating aircraft listed in the Strategic Choices Tool could satisfy their ISR and electronic attack requirements.

growth with increases in the capabilities and capacity of critical enablers, including advanced munitions, secure communications, and more resilient air and space ISR networks. Growing the size of the Air Force's aircraft inventory alone will not create a balanced force capable of future multi-domain operations.

In conclusion, the return of great power competition has closed the window in time where the Air Force could accept increased risk by forgoing major investments to rebuild and modernize its aircraft inventory. Creating a more range-balanced, survivable, and lethal force will require a commitment by the Department of Defense and Congressional leadership to significant increases in the Air Force's annual budget. It will take years of increased funding to rebuild America's air forces following nearly three decades of an advanced aircraft procurement holiday. Further delays to this rebuilding would increase the risk that America's air forces will not keep pace with the military advances of China and Russia.

APPENDIX A

Air Force Aircraft Descriptions

Descriptions of current inventory aircraft in Appendix A are based on online fact sheets published by the Air Force, *Air Force Magazine USAF Almanac 2018*, IHS Jane's website, *IHS Jane's World Air Forces,* and other publications. Descriptions of potential future aircraft and upgrades to current aircraft are based on unclassified, open-source information and estimates developed by CSBA for the purposes of assessing potential future operating concepts and alternative force structures. These descriptions are illustrative and do not represent official requirements or performance characteristics for new aircraft.

Bombers

B-52H Strategic Bomber

Missions: Conventional and nuclear strike.

Range: 8,685 nm.

Armament/payload: Six external hardpoints for 50,000 lb of ordnance and three internal bomb bays for 75,000 lb of ordnance. Can carry up to 36 longer range LRASM-derivative weapons with target discrimination capabilities to support anti-surface warfare missions. Other weapons include JASSM-ER, the Conventional Air-Launched Cruise Missile (CALCM), the nuclear-capable ALCM, the future nuclear Long Range Standoff (LRSO) cruise missile, and likely future hypersonic weapons (not a complete list).

Sensors: New radar expected in the next decade.

Other: The Air Force is planning to re-engine B-52Hs and possibly upgrade other systems to perform its missions though its expected service life.

B-2A Spirit Stealth Bomber

Missions: Conventional and nuclear strike.

Range: 6,300 nm.

Armament/payload: Up to 60,000 lb in two internal weapons bays; can carry nuclear gravity weapons; carries conventional weapons include 16 JASSM-ER, 16 Mk 84s, or the GBU-57 Massive Ordinance Penetrator (not a complete list).

Sensors: AESA radar.

Other: Numerous upgrades to defensive systems, nuclear C2, and other capabilities.

B-1B Conventional Bombers

Missions: Conventional strike.

Range: 6,475 nm.

Armament/payload: 75,000 lb in three internal weapons bays. Can carry 24 JASSMs or a mix of other precision and non-precision weapons (not a complete list). All B-1Bs have been modified to carry conventional weapons only.

Sensors: Scalable Agile Beam Radar–Global Strike (SABR-GS).

(Future) B-21 Raider Stealth Bomber

(Note: Description and capabilities are notional)

Basic description: Intercontinental-range, low-observable aircraft capable of surviving in future contested and highly contested environments.

Missions: Conventional and nuclear strike.

Range: Unknown but likely intercontinental; air refuellable to extend range and mission endurance.

Armament/payload: Internal weapons carriage similar to other bombers (assumed for CSBA gameplay). External weapons carriage would reduce range and increase signature significantly. Will likely carry JASSM-ER and other current weapons, plus next-generation munitions including the LRSO cruise missile and hypersonic weapons.

Sensors: Assume similar to the B-2.

Other: Similar to other advanced modern combat aircraft, assume will have integrated avionics and sensor fusion capabilities that combines information from off-board and onboard sensors to increase situational awareness, and an advanced electronic surveillance measures (ESM) sensor suite.

Fighters and Unmanned Combat Aircraft

F-22 Raptor Air Dominance Stealth Fighter[285]

Basic description: Supersonic fighter for air-to-air operations in contested environments.

Missions: Air-to-air (sweep, escort, defensive counterair) with limited conventional strike capability.

285 U.S. Air Force, "F-22 Raptor," fact sheet, September 23, 2015, available at https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104506/f-22-raptor/.

Range: 500-plus nm estimated unrefueled combat radius, assumes clean configuration, subsonic cruise, internal fuel, and carrying a typical weapons load.

Armament/payload: One 20 mm gun plus eight air-to-air missiles; four air-to-air missiles and two 1,000 lb JDAMs; or four air-to-air missiles and eight Small Diameter Bombs (SDB). Could carry two additional air-to-air missiles externally in missile defense configuration.

Sensors: AESA radar.

Other: Numerous modernization efforts to maintain capabilities needed for operations in contested environments.

F-35A Lightning II Strike Fighters (Conventional Takeoff and Landing)

Basic description: The F-35A is the Air Force's newest 5th generation fighter. The F-35A is optimized for strike operations in contested environments.[286]

Missions: Conventional and nuclear strike, SEAD/DEAD, and close-air support. Has air-to-air capability.

Range: Estimated unrefueled combat radius 700-plus nm; assumes clean configuration and internal fuel plus either two air-to-air missiles and two GBU-31 2,000 lb class internal weapons or four air-to-air missiles carried internally for an air-to-air weapons loadout.

Armament/payload: One 25 mm gun plus capacity to carry 5,700 lb internally and greater than 16,000 lb of weapons externally (22,000 lb total loadout). Internally, can carry four AIM-120 air-to-air missiles; two AIM-120 air-to-air missiles and two bombs up to 2000 lb each; or two AIM-120 air-to-air missiles and eight SDBs. In "Beast Mode" (non-stealth configuration, internal and external carriage), can carry two AIM-9s and fourteen AIM-120s for an air-to-air loadout or two AIM-9s, two AIM-120s, and six GBU-31 2,000 lb class weapons for an air-to-surface loadout (or other variations with other weapons).[287]

Sensors: AESA radar, electro-optical (EO) targeting system/ infrared search and track (IRST), and Distributed Aperture System (DAS) for 360-degree IR detection of missiles and aircraft.

Other: Block 4 software upgrade will add new weapons and sensors and improve the F-35A's EW and other capabilities.

Potential future modifications: Modifications could provide F-35s with enhanced wide area IRST and Light Detection and Ranging (LIDAR), operational flight programs, and

286 U.S. Air Force, "F-35A Lightning II," fact sheet, September 23, 2015, available at https://www.af.mil/About-Us/Fact-Sheets/Display/Article/478441/f-35a-lightning-ii/.

287 Based on an unclassified infographic provided to CSBA by Lockheed Martin on February 19, 2019.

communications to conduct independent and networked ballistic missile engagements and manned-unmanned teaming operations.

F-15C/D Eagles

Basic description: Supersonic, all-weather 4th generation air-to-air fighter.

Missions: Air-to-air (sweep, escort, defensive counterair).

Range: Unrefueled combat radius of 600-plus nm.

Armament/payload: One 20 mm gun plus eight Advanced Medium-Range Air-to-Air Missiles (AMRAAM) or mix of four AMRAAMs and a maximum of four AIM-9X.

Sensors: AESA radar.

(Future) F-15X

Basic description: Supersonic, all-weather 4th generation-plus air superiority fighter.

Missions: Multi-role, conventional strike and air interceptor in permissive and possibly in the low end of the contested environment.

Range: 2,400 nm ferry range with conformal fuel tanks and three external fuel tanks.[288]

Armament/payload: One 20 mm gun plus up to 22 AMRAAMs (various mixes);[289] eight air-to-air missiles and 28 SDBs; or eight air-to-air missiles and up to seven 2,000 lb bombs.[290] Could carry all other weapons the F-15E, F-15SA, and F-15Q can carry. It may be able to carry current and future standoff weapons, depending on their size and weight, decoys, ASAT weapons, and ballistic missile interceptors if there are requirements for them.

Sensors: AESA (APG-82-V1), optical and infrared pods.

Other: The F-15X could perform homeland defense functions to free 5th generation aircraft to prepare for high-end conflicts. It could also conduct standoff strikes and CAS in permissive environments, and it may be suited to support terminal area defenses against ballistic and cruise missile attacks.

288 Based on the F-15E's configuration. See U.S. Air Force, "F-15E Strike Eagle," fact sheet, April 15, 2005, available at https://www.af.mil/About-Us/Fact-Sheets/Display/Article/104499/f-15e-strike-eagle/.

289 Tyler Rogoway, "Exclusive: Unmasking The F-15X, Boeing's F-15C/D Eagle Replacement Fighter," *The Warzone*, July 25, 2018, available at http://www.thedrive.com/the-war-zone/22372/exclusive-unmasking-the-f-15x-boeings-f-15c-d-eagle-replacement-fighter.

290 Ibid.

F-15E Strike Eagles

Basic description: Multi-role, supersonic fighter designed to perform air-to-air and air-to-ground missions at low altitude, day or night, and in all weather.

Missions: Primarily conventional strike. Has air-to-air capability.

Range: Unrefueled combat radius of 600-plus nm.

Armament/payload: One 20 mm gun plus eleven external hardpoints. Can carry up to 15,000 lb of bombs, rockets, or missiles (up to eight AMRAAMs or Sidewinders).

Sensors: AESA radar, multi-spectral targeting pod, Eagle Passive/Active Warning Survivability System (EPAWSS).

F-16 C/D Fighting Falcon

Basic description: Multi-role fighter with all-weather targeting capabilities.

Missions: SEAD/DEAD, conventional strike, nuclear strike if modified to be nuclear-capable, and air-to-air.

Range: Unrefueled combat radius of 500 nm.

Armament/payload: One 20 mm gun plus 16,000 lb weapons capacity (up to six air-to-air missiles).

Sensors: AESA radar, multi-spectral targeting pod.

Other: The F-16 comes in numerous variants (Blocks 25, 30, 32, 40, 42, 50, 52) with varying capabilities.

A-10 Thunderbolt II

Basic description: Twin turbofan close air support aircraft.

Missions: Ground attack and close air support.

Range: Unrefueled combat radius of 540 nm.

Armament/payload: One 30 mm GAU-8/A seven-barrel Gatling gun plus AIM9X Sidewinders and up to 16,000 lb of mixed free-fall or guided ordnance on eight under-wing and three under-fuselage pylon stations.

Sensors: Litening/Sniper Advanced Targeting Pods, advanced datalinks, and other sensors.

Other: Capability to operate from austere airfields.

(Future) Penetrating Counter Air/Penetrating Electronic Attack Aircraft

Basic description: Concept for future aircraft that will be capable of operating in the highly contested environment with greater range and payload than the Air Force's current counterair aircraft.

Missions: Air-to-air, SEAD/DEAD including electronic attack, and limited conventional strike.

Range: Likely capable of long ranges and air refuellable.

Armament/payload: Eight to sixteen AMRAAMS or their future equivalents, four to six Stand-in Attack Weapons, and various EW capabilities.

Sensors: Similar to other advanced penetrating aircraft, sensor suite capable of supplying a fused, multi-domain operational picture using data from a variety of sources.

Other: Provides air superiority and operates as part of a family of systems that could include the B-21 and penetrating ISR systems. A future PCA/P-EA aircraft could help degrade advanced airborne and surface-to-air threats, reducing risk for other penetrating strike platforms and weapons.

(Future) MQ-X Unmanned Combat Air System

Basic description: Follow-on to the MQ-9 designed for operations in future contested environments.

Missions: ISR, strike, and possibly other missions if appropriately equipped.

Range: Unrefueled combat radius of approximately 1,500 nm. Could remain airborne for about 24 hours without aerial refueling.

Armament/payload: 5,000 lb internal weapons payload.

Sensors: Potential to carry AESA radar, EO/IR sensors including IRST, passive SIGINT/ELINT.

Other: Multi-aspect, multi-band RCS reduction and IR signature management equipped with advanced ECM for self-protection. May have low probability of intercept communication and datalinks and advanced onboard data processing including automated target recognition capability.

(Future) Light Attack/Armed Reconnaissance Aircraft (OA-X, AT-X)

Basic description: Non-stealth, multi-role, light attack aircraft for operations in permissive environments.

Missions: Close air support and ground attack, some defensive counterair including limited airbase defense, and homeland defense missions such as counter-narcotics.

Range: 700-plus nm depending on aircraft variant.

Armament/payload: A variety of armament and payloads that could include a datalink, a radar, a defensive suite, and the ability to carry a mix of conventional weapons.

Sensors: Could be equipped with sensors that are carried by MQ-9-class RPAs and fighter aircraft.

Other: Low operational cost-per-flying-hour could likely reduce the cost of supporting overseas contingency operations in permissive environments.

ISR and BMC2 Aircraft (UAS only)

RQ-4 Global Hawk UAS

Basic description: High-altitude, long-endurance UAS.

Missions: Long-range strategic ISR, SIGINT, and GMTI.

Range: 10,700 nm, 32-plus hours mission endurance.

Sensors: Electro-optical, infrared, synthetic aperture radar and high- and low-band SIGINT, GMTI sensors.

(Future) Penetrating ISR (P-ISR) Aircraft

Basic description: Penetrating ISR aircraft with long-range and long-mission persistence.

Missions: ISR in contested and highly contested environments to provide other penetrating capabilities with information on the disposition of enemy forces, emerging threats, and mobile/relocatable targets.

Range: Long-range aircraft.

Armament/payload: Assume it could have some self-defense capabilities.

Sensors: Assume it could have active and passive, multi-domain sensors.

Other: A P-ISR aircraft that can persist in contested areas would reduce the U.S. Joint Force's reliance on increasingly vulnerable overhead sensor networks and be more responsive than overhead systems to the dynamic conditions of the future battlespace.

(Future) Advanced Battle Management System

Basic description: A notional multi-domain system-of-systems that would perform missions now conducted by the E-3 AWACS and E-8 JSTARS.

Missions: ISR, BMC2, wide-area aerial surveillance, GMTI, and AMTI.

Range: Long-range system.

Armament/payload: May have some self-protection capabilities.

Sensors: A multi-domain system-of systems that integrates information from multiple sensors to provide a dynamic picture of the battlespace.

Other: This study assumed the future ABMS will be a BMC2 capability that will integrate advanced sensors from land, sea, air, and space to provide a common ground and air picture. Systems could include teamed manned and unmanned aircraft, resilient space/cyber capabilities, and other systems.

MQ-9 Reaper RPA

Basic description: Medium- to high-altitude RPA for ISR and light attack.

Missions: ISR and light attack; future missions could include airbase defense and support to homeland defense.

Range: 1,150 nm, 34 hours mission endurance.

Armament/payload: Seven hardpoints for up to 3,086 lb of bombs and short-range missiles.

Sensors: Synthetic aperture radar and Multi-Spectral Targeting System.

Other: If appropriately modified, the MQ-9 may be able to conduct a variety of possible new missions, including missile defense and airbase defense.

(Future) Multi-Mission UAS

Basic description: A fighter-sized UAS with modular payload configurations to perform multiple missions in permissive and lightly contested environments.

Missions: Could perform a wide range of missions, including airbase missile defense, counter-UAS, conventional strikes, ISR, electronic warfare, and homeland defense.

Range: Unrefueled combat radius of approximately 2,000 nm. Maximum flight time is approximately 30 hours depending on load out and mission profile.

Armament/payload: Four to six air-to-air missiles or four Airborne Weapons Layer interceptor missiles. Could have sufficient space, weight, electric power generation, and

cooling to carry a 150kW-class high energy laser (HEL) and possibly other future directed energy weapons.

Sensors: Baseline sensors consist of a 360-degree active radar and IR defensive sensors. Mission-specific payload options include a GMTI radar and electronic surveillance and electronic attack systems.

Other: A future Airborne Weapons Layer missile defense system-of-systems could include a suite of sensors that provide 360-degree surveillance, wide-area search and track, and fire control using active, passive, and multi-static radio-frequency sensors, IRST, and LIDAR. A force of MM-UAS could also support mesh communication networks that extend into contested environments.

Air Refueling Tanker Aircraft[291]

KC-135R/T

Basic description: Medium-range tanker.

Missions: Aerial refueling with some cargo and aero-medical evacuation capabilities.

Offload/payload/passengers: Can provide maximum offloads of 142,000 lb at 500 nm; 117,100 lb at 1,000 nm; 98,800 lb at 1,500 nm; or 77,800 lb at 2,000 nm. Carries a payload of six pallets and 13 short tons. Has the capacity to carry 36 passengers. For aeromedical missions, can carry 15 litters/20 ambulatory patients.

Other: Has a maximum takeoff fuel of 200,000 lb; a fuel burn rate of 11,291 lb per hour; and requires 0.6 C-17 parking spots. Some KC-135Ts are air refuellable, which increases their range, mission endurance, and fuel off-load potential per mission.

KC-10

Basic Description: Long-range tanker.

Missions: Aerial refueling and cargo and passenger carrying capabilities.

Offload/payload/passengers: Can provide maximum offloads of 247,500 lb at 500 nm; 207,500 lb at 1,000 nm; 168,800 lb at 1,500 nm; or 131,000 lb at 2,000 nm. Carries a payload of 23 pallets and 32 short tons. Has the capacity to carry 68 passengers.

291 Data in the descriptions for the KC-135R/T, KC-10, and KC-46A come from U.S. Air Force, "Air Mobility Planning Factors," Air Force Pamphlet 10-1403, October 24, 2018, available at https://static.e-publishing.af.mil/production/1/af_a3/publication/afpam10-1403/afpam10-1403.pdf.

Other: Has a maximum takeoff fuel of 340,000 lb; a fuel burn rate of 18,948 lb per hour; and requires 1.0 C-17 parking spots. KC-10s are air refuellable, which increases their range, mission endurance, and fuel off-load potential per mission.

KC-46A

Basic description: Medium-range tanker.

Missions: Aerial refueling with cargo and aero-medical evacuation capabilities.

Offload/payload/passengers: Can provide maximum offloads of 163,100 lb at 500 nm; 140,200 lb at 1,000 nm; 117,300 lb at 1,500 nm; or 71,400 lb at 2,000 nm. Carries a payload of 18 pallets and 32 short tons. Has the capacity to carry 98 passengers. For aeromedical missions, can carry 24 litters/30 ambulatory patients.

Other: Has a maximum takeoff fuel of 208,000 lb; a fuel burn rate of 11,000 lb per hour; and requires 0.87 C-17 parking spots. KC-46A are air refuellable, which increases their range, mission endurance, and fuel off-load potential per mission.

(Future) Concept for a Theater Tanker Aircraft[292]

Basic Description: Potential new optionally manned tanker design with passive defense measures that would enable it to penetrate for some distance into contested areas.

Missions: Aerial refueling in theater for most aircraft; optimized for fighters and other aircraft, so that their refueling can be done in some contested environments; could penetrate one or two hundred miles into contested environments to help extend the range of penetrating aircraft.

Offload/payload/passengers: Maximum offload would be 60,000 lb at 750 nm; 50,000 lb at 1,100 nm; or 30,000 lb at 1,900 nm. Could have C-27 class cargo and passenger capability.

Sensors: Multiple sensors for situational awareness and some self-protection.

Other: Could have a maximum takeoff fuel of 91,000 lb; a fuel burn rate approximately 30 percent less than a KC-135R; and would require 0.5 C-17 parking spots (similar to a C-130). Could be air refuellable, which would increase range, mission endurance, and fuel off-load potential per mission. It could also have a signature managed configuration that would enable it to operate in the low end of contested environments to support 5th generation fighters within their internal fuel radius of the threat. Sized for tactical employment operations, not for trans-oceanic "fighter drags" or refueling bombers and other heavy aircraft. Could have C-130-class airfield performance.

292 Barth Shenk, Air Force Research Laboratory (AFRL), Aerodynamic Technology Branch (RQVA), "Advanced Tanker Concepts and Enabling Technologies," PowerPoint briefing provided at a CSBA workshop, October 16, 2018.

(Future) Concept for a Lightweight and Efficient Tanker[293]

Basic description: Lightweight, dedicated new-design tanker that is optimized for very long range, affordable and efficient aerial refueling in permissive and lightly contested environments.

Missions: Dedicated to aerial refueling only and focused on transoceanic refueling of combat and other aircraft.

Range: Very-long-range tanker.

Offload/payload/passengers: Maximum offload of 104,000 lb at 500 nm; 94,000 lb at 1,000 nm; 74,000 lb at 2,000 nm; or 53,000 lb at 3,000 nm. No payload or passenger capacity.

Other: Smaller, lightweight tanker that could have an estimated 40 percent reduced fuel burn rate compared to current Air Force tankers to increase its fuel offload potential. Small parking footprint similar to a C-130. Could be designed to have a reduced aircraft weight to increase its range-offload performance without exclusively relying on advanced aerodynamic technologies. Air refuellable.

(Future) Concept for a UAV Tanker Aircraft

Basic description: A UAS with new boom technology designed primarily for aerial refueling.

Missions: Primarily aerial refueling. Refuels other UAS to extend their endurance, fighters, and some larger aircraft. Could also be designed to perform ISR and other missions; could be a version of the MM-UAS or the MQ-X UCAV.

Range: Long-range tanker; range potential depends on fuel offloads.

Offload/payload: 30,000 lb fuel offload at 500 nm.

Sensors: Sensors for a variety missions could be incorporated in the original design or added in the future, depending on requirements.

Other: Refuels other UAVs, extending their endurance from hours to days. Could also refuel and extend fighter-sized aircraft and other tanker aircraft. Air refuellable.

293 Mike Stokesdale, Air Mobility Command/A10N, "Lightweight Tanker Concept," PowerPoint briefing provided at a CSBA workshop, October 16, 2018. The views and position regarding this future aircraft are those of Mike Stokesdale and do not reflect the official position of the Air Mobility Command, the Department of Defense, or the U.S. Government.

APPENDIX B

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APPENDIX C

Legislation Requiring Aircraft Inventory Studies for The Air Force

National Defense Authorization Act for Fiscal Year 2018, P.L. 115-91, 131 Stat. 1283 (2017), Section 1064, Studies on Aircraft Inventories for the Air Force.

SEC. 1064. STUDIES ON AIRCRAFT INVENTORIES FOR THE AIR FORCE.

(a) INDEPENDENT STUDIES.

(1) IN GENERAL.—The Secretary of Defense shall provide for the performance of three independent studies of alternative aircraft inventories through 2030, and an associated force-sizing construct, for the Air Force.

(2) SUBMITTAL TO CONGRESS.—Not later than March 1, 2019, the Secretary shall submit the results of each study to the congressional defense committees.

(3) FORM.—The result of each study shall be submitted in unclassified form, but may include a classified annex.

(b) ENTITIES TO PERFORM STUDIES.—The Secretary shall provide for the studies under subsection (a) to be performed as follows:

(1) One study shall be performed by the Secretary of the Air Force, in consultation with the Director of the Office of Net Assessment.

(2) One study shall be performed by a federally funded research and development center.

(3) One study shall be conducted by an independent, nongovernmental institute, which is described in section 501(c)(3) of the Internal Revenue Code of 1986 and exempt from taxation under section 501(a) of such Code, and has recognized credentials and expertise in national security and military affairs.

(c) PERFORMANCE OF STUDIES.

(1) INDEPENDENT PERFORMANCE.—The Secretary shall require the studies under this section to be conducted independently of one another.

(2) MATTERS TO BE CONSIDERED.—In performing a study under this section, the organization performing the study, while being aware of current and projected aircraft inventories for the Air Force, shall not be limited by such current or projected aircraft inventories, and shall consider the following matters:

(A) The national security and national defense strategies of the United States.

(B) Potential future threats to the United States and to United States air and space forces through 2030.

(C) Traditional roles and missions of the Air Force.

(D) Alternative roles and missions for the Air Force.

(E) The force-sizing methodology and rationale used to calculate aircraft inventory levels.

(F) Other government and nongovernment analyses that would contribute to the study through variations in study assumptions or potential scenarios.

(G) The role of evolving technology on future air forces, including unmanned and space systems.

(H) Opportunities for reduced operation and sustainment costs.

(I) Current and projected capabilities of other Armed Forces that could affect force structure capability and capacity requirements of the Air Force.

(d) STUDY RESULTS.—The results of each study under this section shall

(1) identify a force-sizing construct for the Air Force that connects national security strategy to aircraft inventories;

(2) present the alternative aircraft inventories considered, with assumptions and possible scenarios identified for each; (3) provide for presentation of minority views of study participants; and

(4) for the recommended inventories, provide

(A) the numbers and types of aircraft, the numbers and types of manned and unmanned aircraft, and the basic capabilities of each of such platforms;

(B) describe the force-sizing rationale used to arrive at the recommended inventory levels;

(C) other information needed to understand the aircraft inventories in basic form and the supporting analysis; and

(D) options to address aircraft types whose retirement commences before 2030.

LIST OF ACRONYMS

A2/AD	anti-access/area denial
AAM	air-to-air missile
ABMS	Advanced Battle Management System
ACA	Aerospace Control Alert
ACC	Air Combat Command
ADIZ	air defense identification zone
AESA	active electronically scanned array
AEW&C	airborne early warning and control
AFSOC	Air Force Special Operations Command
ALCM	air-launched cruise missile
AMC	Air Mobility Command
AMRAAM	Advanced Medium-Range Air-to-Air Missile
AMTI	airborne moving target indicator
ASAT	anti-satellite
AWACS	Airborne Warning and Control System
BMC2	battle management and command and control
BUR	Bottom-Up Review
C2	command and control
C2ISR	command, control, intelligence, surveillance, and reconnaissance
C3	command, control, and communications
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CAF	combat air forces
CALCM	Conventional Air-Launched Cruise Missile
CAP	combat air patrol
CAS	close air support
CCD	camouflage, concealment, and deception
CONOPS	concept of operations
CRAF	Civil Reserve Air Fleet
CSAR	combat search and rescue
DCA	defensive counterair
DoD	Department of Defense
ECS	East China Sea
EM	electromagnetic
EMS	electromagnetic spectrum
EO	electro-optical
EO/IR	electro-optical/infrared
EPAWSS	Eagle Passive/Active Warning Survivability System

ESM	electronic surveillance measures
EW	electronic warfare
FPC	force planning construct
FVB	Fleet Viability Board
FYDP	Future Years Defense Program
GLCM	ground-launched cruise missile
GMTI	ground moving target indicator
GPS	Global Positioning System
HALE	high-altitude long-endurance
HEL	high energy laser
HF	high frequency
HGV	hypersonic boost-glide vehicle
HVAA	high-value airborne asset
IADS	integrated air defense system
ICBM	intercontinental ballistic missile
ICD	Initial Capabilities Document
IFPC	Indirect Fire Protection Capability
INF Treaty	Intermediate-Range Nuclear Forces Treaty
IRBM	intermediate-range ballistic missile
IRST	infrared search and track
ISR	intelligence, surveillance, and reconnaissance
JASSM	Joint Air-to-Surface Standoff Missile
JASSM-ER	Joint Air-to-Surface Standoff Missile–Extended Range
JDAM	Joint Direct Attack Munition
JSTARS	Joint Surveillance and Target Attack Radar System
LACM	land attack cruise missile
LEO	low Earth orbit
LIDAR	Light Detection and Ranging
LPI/LPD	low probability of intercept/low probability of detection
LRASM	Long-Range Anti-Ship Missile
LRIP	low rate initial production
LRSO	Long Range Standoff cruise missile
MADL	Multifunction Advanced Datalink
MAF	mobility air forces
MANPADS	man-portable air-defense systems
MCRS	Mobility Capability Requirements Study
MM-UAS	Multi-Mission Unmanned Aerial System
MRBM	medium-range ballistic missile
MRC	major regional conflict
NAOC	National Airborne Operations Center
NASIC	National Air and Space Intelligence Center

NATO	North Atlantic Treaty Organization
NDAA	National Defense Authorization Act
NORAD	North American Air Defense Command
O&M	operations and maintenance
O&S	operations and support
OCA	offensive counterair
OCO	overseas contingency operations
PCA	Penetrating Counter Air
P-EA	Penetrating Electronic Attack
PGM	precision-guided munition
PLA	People's Liberation Army
PLAAF	People's Liberation Army Air Force
PLAN	People's Liberation Army Navy
PLARF	People's Liberation Army Rocket Force
PMAI	primary mission aircraft inventory
PNT	positioning, navigation, and timing
QDR	Quadrennial Defense Review
REMIS	Reliability and Maintainability Information System
RPA	remotely piloted aircraft
RPO	rendezvous and proximity operations
SABR-GS	Scalable Agile Beam Radar–Global Strike
SAM	surface-to-air missile
SCS	South China Sea
SDB	Small Diameter Bomb
SEAD/DEAD	suppression of enemy air defenses/destruction of enemy air defenses
SiAW	Stand-in Attack Weapon
SLBM	submarine-launched ballistic missile
SOF	special operations forces
SRBM	short-range ballistic missile
TAI	total aircraft inventory
TEL	transporter erector launcher
THAAD	Terminal High Altitude Area Defense
UAV	unmanned aerial vehicles
UCAS	Unmanned Combat Air System
UCAV	unmanned combat aerial vehicle
VHF	very high frequency
VKS	Russian Aerospace Forces
VLRAAM	very-long-range air-to-air missile
WMD	weapons of mass destruction

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