

MITRE U.S. Air Force Aircraft Inventory Study Executive Summary

The Office of the Secretary of Defense selected the MITRE Corporation to conduct an independent study of U.S. Air Force aircraft inventories through 2030, as directed by the Fiscal 2018 National Defense Authorization Act. The study primarily focused on the demands of sustained, high-intensity combat operations in the Indo-Pacific theater.

MITRE's study analytically explored basing needs, threats to bases, mission requirements, and the aircraft needed to perform those missions.

Operational effectiveness is significantly impacted by basing and logistical support, especially when U.S. forces play an "away game" thousands of miles from the mainland U.S. Unsurprisingly, aircraft flying from bases closer to a combat zone can generate more combat power in a permissive environment, but they are also at far greater risk to enemy attack. Chinese and Russian anti-access/area denial capabilities are significant and will only become more lethal and plentiful by 2030.

Basing in rear areas is safer but requires more aircraft and logistical support to generate the same combat power. The Air Force needs additional long-range aircraft, especially high-capacity bombers, to strengthen conventional deterrence. Simply put, deterrence is stronger if an adversary knows the U.S. retains significant combat power even if it loses access to close-in bases.

Overall, the U.S. needs additional basing options in both forward and rear areas. Bases should be better supported through defensive systems, decoy and deception measures, and new concepts of operations.

There are important correlations between fleet size and operating cost that should inform future procurement decisions. The most commonly cited operating cost metric, cost per flying hour, does not capture a fleet's fixed operating and support (O&S) expenses. Total expenses (fixed plus variable costs) are not linear: Per aircraft average O&S costs rise dramatically when fleets are smaller than approximately 150 aircraft. Average O&S costs are far lower and level off in fleets larger than 150. This is generally true for all manned aircraft, regardless of mission type.

The Air Force needs additional combat power to meet the requirements laid out in the National Defense Strategy. This requires not just more aircraft, weapons, and bases, but also a higher state of readiness. Many aircraft types currently languish with mission capable (MC) rates in the 50%-60% range; these need to be brought up and kept above 80%. Doing so has the same combat effect as buying additional aircraft and avoids the perils of building a "hollow force."

To support long-range operations, the Air Force should prepare four additional rear-area bases to serve as bomber and tanker operating locations. These bases could be on U.S. territory, or in nations such as Australia or Papua New Guinea. Since no new bombers are currently in production, the Air Force should delay any bomber retirements until the B-21 is available in significant numbers.

Tankers are absolutely vital for long-range combat operations. To preserve an adequate refueling capability, planned KC-10 retirements should be delayed until KC-46 deliveries normalize. Further, KC-46 deliveries should continue indefinitely at an economic minimum rate, to replace additional KC-135s.

F-35As cannot be delivered fast enough to replace geriatric 4th generation fighters rapidly nearing the end of their service lives. New plans are needed. USAF should purchase F-35As at least in the quantities laid out in the Fiscal 2019 budget and up to 54 aircraft per year. A-10s and F-16s should be retired as F-35s become available. Despite the fiscal temptations, F-35A buys should not be reduced to pay for other aircraft.

In addition to the F-35A, the Air Force should buy advanced new F-15s. Over time, these should replace, in a single configuration, existing C/D/E-model F-15s that will become increasingly obsolescent through 2030.

An armed version of the T-X trainer could perform vital homeland defense missions that don't require more advanced (and expensive) frontline fighters. The U.S. should therefore accelerate T-X purchases and produce the trainers along with an F/T-X configuration for homeland defense missions and likely export sales.

Strategic airlift capabilities are stable for the time being, but no intertheater airlifters are in or near production. USAF must either have a new strategic airlifter or a C-17 service life extension program in place by 2030.

These basing, readiness, and acquisition recommendations are needed to ensure a credible, deterrent force capable of meeting the demands of the National Defense Strategy. An effective force cannot be bought all at once, it will require commitment and sustained investment. Taken together, these investments represent approximately a 10% increase over the USAF's aircraft-only planning baseline through 2030.

MITRE U.S. Air Force Aircraft Inventory Study Unclassified Report

Introduction

The Office of the Secretary of Defense selected MITRE as the Federally Funded Research and Development Corporation (FFRDC) to conduct one of three independent studies of U.S. Air Force aircraft inventories through 2030, as directed by the fiscal year 2018 National Defense Authorization Act. Section 1064 specified an unclassified study with a classified annex. The subject matter, Air Force classification guidance, and MITRE's findings required a classified report, published as MITRE Technical Report 190153. MITRE provides this unclassified summary for broader dissemination.

MITRE took a three-stage approach to complete the study with a primary focus on meeting the demands of sustained, high-intensity combat operations in the Indo-Pacific theater. While the U.S. hopes to never engage in a shooting war with China, theoretical battles in this region represent stressing scenarios useful for planning the 2030 Air Force.

First, MITRE developed an aircraft beddown optimization model. This analyzed basing options and geography, threats to bases, base defenses, aircraft payloads, and scenario-based mission taskings to determine capability and capacity to "get to the fight." The model included both land and seabasing to develop implications for aircraft inventories for the entirety of the theater using a formulation that has not previously been accomplished at this scale.

Second, MITRE developed cost analyses based on Air Force data and related studies to estimate the fiscal implications of the findings that emerged from the beddown model.

Finally, the study includes the results of previous relevant MITRE analyses.

MITRE focused on fighters, bombers, tankers, and trainers, including unmanned aerial vehicles (UAVs). The study also included limited aspects of special mission (command, control, intelligence, surveillance, reconnaissance and battle management) and strategic airlift aircraft. All told, these fleets represented 4,300 of the 5,349 aircraft in the Air Force inventory as of the end of fiscal year 2017. In terms of UAVs, MITRE focused on basing, mission, and aircraft performance rather than tradeoffs based on how they are piloted.

Overall Findings

The first overarching finding concerns not aircraft, but the basing of aircraft. Aircraft flying combat missions face operational constraints based on the availability of basing and logistics. These constraints, further informed by various threats and defenses, determine the operational utility of various aircraft types.

Simply due to enroute flight time, the further aircraft are based from an operations area, the less combat power or time on station they can deliver during a set period. This assumes aerial refueling is available and aircraft can reach the operating area, employ and recover within the maximum sortie duration limits. From this it follows that more distant basing requires more

aircraft to achieve the same operational intensity and to execute the same missions. Distant basing may also change the mix of aircraft best suited to fly those missions.

Forward land- and seabased aircraft are very vulnerable to the anti-access/area denial (A2/AD) threats that exist today, threats that will only become more lethal and plentiful by 2030. These A2/AD systems can destroy aircraft on the ground or ship decks. Many key U.S. allies are located in forward areas, as are the U.S. bases these nations host, and these allies operate substantial air forces. Should hostilities begin, the geography of forward bases will make them tempting targets for enemy A2/AD systems, and adversary attacks could result in large U.S. and allied losses in a short period of time.

In the European theater, the 1987 Intermediate Nuclear Forces (INF) treaty between the USSR, now Russia, and United States forbade the development and deployment of weapons ranging from 500 km to 3,500 km. China was not party to the INF treaty and during the past three decades has developed and deployed numerous systems and thousands of weapons of the kind the INF treaty limited.

The U.S. has not had large wartime aircraft ground losses in decades. Since the end of World War II, the U.S. military has frequently operated from forward airbases, but they have been sanctuaries largely immune from enemy attack. Infrequent and low losses may have made U.S. forces and planners complacent about the risk of forward basing. Today, there are insufficient bases and logistical infrastructure to conduct large-scale operations from geographically lower risk, more distant middle-tier and rear bases.



There is a significant tradeoff between mission and losses: Basing aircraft farther away from adversary threats can dramatically decrease ground losses at the cost of a slightly lower operational tempo. The capabilities and numbers of aircraft that are able to operate from more distant bases drive the achievable operational tempo, and this is why basing is so important for the Air Force inventory. From the defensive perspective, not only do distant bases reduce the number and variety of adversary weapons able to target them, they increase the defensive response time and battlespace depth.

The mission-survival tradeoff is critical. Today's aircraft are a limited resource and their development and production takes time -- longer than the expected duration of a high-intensity war. Aircraft losses that cannot be backfilled from existing inventory are effectively permanent.

Basing aircraft farther away from the adversary, however, is not always operationally possible or diplomatically acceptable to allies and partners. South Korea and Germany, to cite just two examples, have certain expectations about how the U.S. would base aircraft and fight alongside them in wartime.

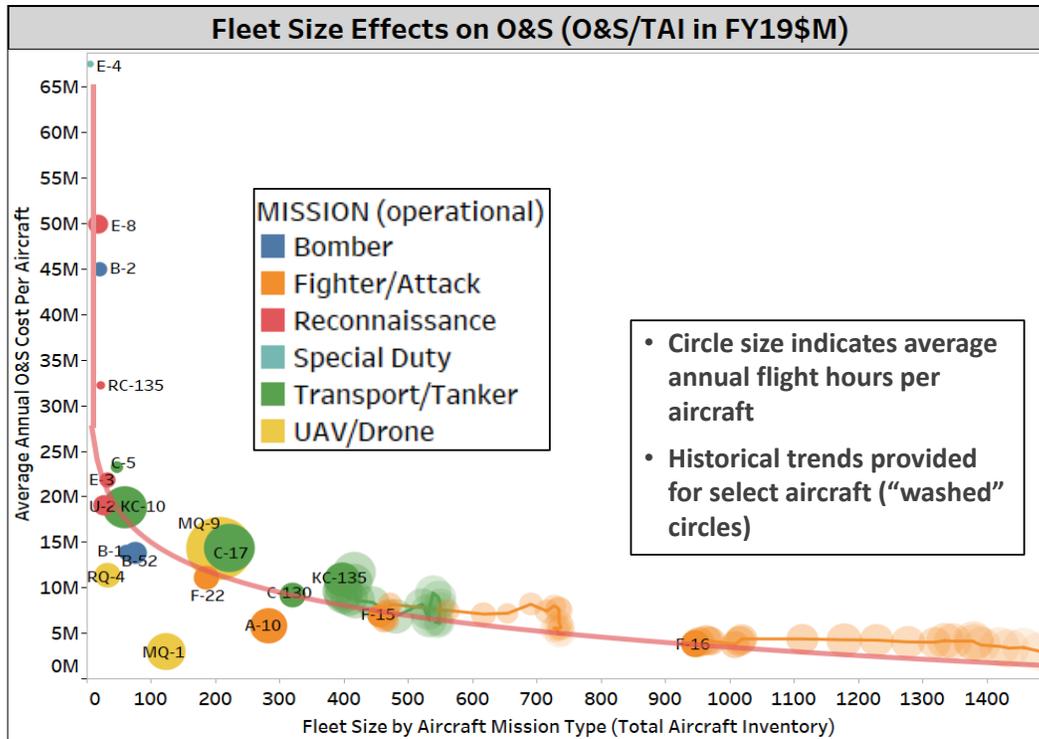
The second overarching finding is that an increase in available long-range aircraft and bases to support them can strengthen the conventional deterrence posture of U.S. forces. Long-range aircraft with unambiguous, high capacity conventional capabilities based beyond the A2/AD high-threat region must be able to strike the adversary through both standoff and penetrating deliveries.

Concurrently, the risk to forward-based forces can be reduced. This can be achieved by increasing the number of bases that aircraft fly from at a variety of operational ranges; by greater use of decoy and deception techniques; and by expanding the availability of defensive systems such as Patriot air defense batteries and hardened aircraft shelters (HASs). Combined with a revised concept of operations from forward bases, a conventional deterrent posture with a significant and credible long-range attack capability provided by bombers and rear bases ensures the U.S. can counterattack in force -- creating a security dilemma for the adversary.

The third overarching finding concerns aircraft fleet sizes and the total cost of owning and operating them. Total aircraft operations and sustainment (O&S) costs have two components. Fixed costs, such as the need to maintain specialized training and maintenance networks, are independent of flight hours. Variable costs, such as fuel expenses, are more directly tied to flight hours. With few exceptions, the fixed costs are far larger than the variable costs, and fixed costs strongly depend on fleet size.

The U.S. Air Force has historically used cost per flying hour as its primary metric for aircraft costs for budget planning and deliberations, but this metric tends to mask the underlying fixed costs of ownership. Regardless of flight hours, there are economies of scale for larger fleets of aircraft because fixed costs are amortized over more aircraft. Average fleet sustainment costs per aircraft are not linear: Small fleets have dramatically higher costs than large fleets, and based on historical data, the knee in the curve is approximately 150 aircraft. Total cost per aircraft for fleet

sizes of less than 150 rise dramatically, whereas they taper off equally significantly for fleets of more than 150.¹



Past data follows this pattern regardless of the aircraft or mission, and it also is reflected in aircraft with large inventories that gradually decrease due to retirements, as indicated in the diagram for the F-15, F-16, and KC-135. There is much work to do to achieve economic sustainment for the F-35A and B-21, but the Air Force should seek to exploit the economies of scale inherent in larger inventories and avoid small fleets when procuring new aircraft.

Overall Recommendations

Air Force aircraft need to be significantly recapitalized, brought to a higher state of readiness, and provided with multiple new bases to operate from. These changes will not be inexpensive, but in the aggregate their cost does not differ dramatically from existing defense plans. The change requires committed, sustained investment.

The Air Force needs to increase many of its aircraft inventories. Delaying aircraft retirements until replacements are available to replace them reduces risk to the nation. For aircraft nearing the end of their production runs, it will often be wise to keep the production lines open at an economic minimum production rate to bridge to new capabilities. Extended low-rate production

¹ The Northrop Grumman Analysis Center originally made this observation, cited with permission. During this study, MITRE verified the result from the 2017 Air Force Total Ownership Cost database.

also hedges against future uncertainty and the high cost of restarting production or designing and developing a wholly new aircraft.

Bombers

In the MITRE analysis, bombers delivered large payloads from distant bases with minimal risk of ground losses. They did not stress the tanker fleet, requiring no more than 20% of total available fuel offload across numerous scenarios.

There are no bombers currently in production, however. B-21 deliveries are forecast to begin in the mid-2020's, but the B-21 will not add significant operational capacity until after 2030. Additionally, the B-52 fleet is slated to receive new engines, and while this overhaul will enhance range, payload, and readiness, bomber availability will be stressed while the fleet is re-engined.

The U.S. possesses 62 B-1s, 20 B-2s and 75 B-52s, however the low mission capable (MC) rates of these aircraft means fewer than 100 of the 157 bombers are available to fly at any given time.² If the entire fleet of bombers had an MC-rate of 80% or higher, nearly 30 extra bombers would be available for missions.

Maintain Today's Bomber Fleet

Because no new bombers will enter the Air Force inventory until the mid-2020s, **MITRE recommends immediate, sustained investment to maintain 80% or higher mission capable rates across the current bomber fleets. MITRE recommends considering no bomber retirements until there are at least 50 operational B-21s bombers in the inventory in the mid 2030s.** If possible with low risk to the program, consider accelerating B-21 production, and consider extending production beyond the planned 100 B-21s before proceeding with further legacy bomber retirements.

Bomber Bases

Bombers project combat power over long range, but the longer the range, the more that power is diluted. Main Indo-Pacific operating bases for bombers outside the mainland United States include Anderson AFB (Guam), Hickam AFB, Hawaii, and the more distant Diego Garcia (U.K.) in the Indian Ocean. Bombers have the largest basing and support footprint of any aircraft in the USAF inventory, requiring long runways, lots of ramp space, voluminous fuel and weapons storage, defenses, and support equipment and personnel.

The U.S. should select and expand four additional bases in the Indo-Pacific for the purpose of making them available as bomber and tanker operating locations. They should be able to host operations of up to 24 bombers and a complement of 18 tankers. These bases could be located on U.S. territories or allied and partner nations such as Australia and Papua New Guinea. These bases should be provisioned with protective aircraft shelters as well as defensive and deception systems to enhance bomber survivability.

² B-1 = 53%, B-2 = 54%, B-52 = 72% as of 2017 - Air Force data, <https://www.airforcetimes.com/news/your-air-force/2017/04/02/growing-readiness-woes-only-7-in-10-air-force-planes-are-ready-to-fly/> Stephen Losey

Bomber Weapons

Long-range standoff weapons are generally more complex and expensive than short-range and direct attack munitions. Until the B-21 is operational, only the B-2 has some capability to penetrate enemy defenses and employ shorter range weapons in the face of advanced enemy defensive systems. There are 20 B-2s, with roughly half mission capable, so the penetration capability is minimal for the near future.

MITRE recommends further development, procurement, and deployment of large magazines of long-range standoff weapons able to penetrate and counter the A2/AD threats to bases. In the short term, these weapons will be the only penetrating capability available in quantity, regardless of the launching bomber. In the long term as the B-21 becomes operational, such weapons will continue to keep the B-1 and B-52 fleets relevant against advanced enemy defenses.

With these recommended improvements in bomber mission capable rates, basing, defenses, and weapons, U.S. forces in the Indo-Pacific will project a much stronger conventional deterrence posture. This posture will provide operational stability and flexibility that does not exist today, and is an important component in reducing the forward basing risk of U.S. and allied forces.

Tankers

In a vast maritime theater, destroying tankers cripples combat power as much as destroying fighters or bombers.

Tanker capacity was at its limits in MITRE's modeled scenarios with fighters requiring 60-70% of fuel offloads and bombers averaging 20%, as noted earlier. Navy and Marine Corps fighter aircraft consistently required large volumes of air refueling, and this was included in the fighter offload percentages. Rear basing decreased available offloads because the tankers themselves had to burn more fuel to reach refueling points located far forward.

Tanker production

KC-46A deliveries are just beginning, and the challenges are well publicized. The KC-10 fleet is slated for retirement, but **MITRE recommends delaying KC-10 retirements until KC-46A deliveries normalize.** KC-46A production will reach the planned 179 aircraft in the late 2020s. **USAF should then continue KC-46 production indefinitely at 10 or more aircraft per year, to accommodate antiquated KC-135R retirement schedules and grow the tanker fleet, as planning will likely require.**

Tanker basing

As with bombers, tankers require additional basing options which include a fuel supply infrastructure able to support combat operations tempos. Many of these bases would best be located in the current "flyover" areas of the Pacific (e.g., between Hawaii and Guam) to keep tankers available for operational taskings while reducing their vulnerability to A2/AD threats.

Other tanker capabilities

MITRE's Tanker-Receiver Placement Model (TRPM) revealed how ubiquitous tankers would be during Indo-Pacific combat operations. The TRPM model is the first of its kind to be able to

optimize aircraft beddowns in a theater as large and complex as the Indo-Pacific. TRPM modeling showed tanker routing completely covers the paths of bombers, fighters, and other support and special mission aircraft. The tanker routing structure suggests that these aircraft are ideally positioned to economically serve other roles, such as distributed communications and datalink relays, rather than investing in new special purpose aircraft to satisfy the same requirements.

Fighters

Fighters are fundamentally short-range aircraft. Assuming adequate aerial refueling availability, all fighters have a similar maximum combat mission duration of about 10 hours. This a human limit, not an aircraft limit, and it poses a basing dilemma: Forward bases are vulnerable, but rear bases may place fighters beyond their useful or even maximum operational radius. Assuming combat mission duration and radius is the same for all, fighters with larger weapons payloads offer greater combat power over time. (Note: Due to classification and scope, MITRE could not include tactical mission effectiveness or vulnerability of aircraft as part of this study.)

The Air Force's 4th generation fighters are reaching the end of their service life faster than 5th generation F-35As can be economically delivered and brought into service. The oldest 4th generation fighters are the A-10C and F-15C/D.

F-35A Production

Continue producing the F-35A at the Air Force's FY-19 planned rate (quickly ramping to at least 47 and then 54 aircraft per year) through 2030. While MITRE also recommends other new fighter purchases, it is important that F-35A acquisition is not reduced to pay for other aircraft acquisitions.

F-15NG production and F-15C/D/E Retirements

Beginning as soon as possible, procure an F-15NG ("next generation") at a rate of 24 aircraft per year to enable F-15C/D retirements. Continue procurement of F-15NGs to cover F-15E retirements in a single common F-15 configuration. The Air Force bought its last F-15E Strike Eagle in 2001, but the F-15 production line remains open for foreign military sales. The F-15NG should be a dual role air-to-air and air-to-ground fighter based on the F-15E aircraft with updated sensors, maximized payload, and 5th generation datalinks to enable interoperability with the F-35A and perhaps the F-22.

A-10 and F-16C/D Retirements

Retire the A-10C at the rate of F-35A deliveries, followed by the F-16C/D aircraft as they reach the end of their service life. Reassign Airmen supporting these aircraft to the F-35A.

F/T-X Light Jet Fighter for Homeland Defense and Export

Unlike overseas contingency operations, Homeland Defense aircraft operate in a permissive environment with a robust infrastructure. Using front-line 4th and 5th generation fighters for this mission is expensive and misallocates valuable service life that would be better used to train and conduct "away game" combat operations.

The Air Force will soon begin production of the T-X, a jet trainer designed specifically to prepare aircrew for 5th generation aircraft. This same aircraft can be adapted to economically accomplish the Homeland Defense mission by outfitting it with a radar, aerial refueling, a stronger wing for weapons carriage, and armament control. This can be done for lower acquisition, operating, and support costs than using advanced frontline combat aircraft for this mission.

Purchase approximately 400 F/T-X aircraft to outfit 15 squadrons to supplement the Homeland Defense mission. F/T-X modifications and U.S. acquisition will position this aircraft for foreign military sales to nations for which the F-15, F-16, or F-35 are either too expensive or too complex to operate, or nations desiring an economical complement to their existing fighters. The F/T-X light fighter will also provide further opportunities for shared training and operations with allied and partner nations.

Mission Capable Rates

Invest in the spares, maintainers, and resources necessary to raise fighter MC rates to 80% or higher. Fighters suffer from similar reliability problems as bombers, with 4th generation fighters averaging 70% MC and 5th generation fighters at or below 50%. DOD's leadership has called on the Air Force and Navy to quickly increase key fighter MC rates to 80%, but this must also be a sustained effort.

Fighter Basing

Fighters also need more basing options, but for different reasons than bombers and tankers. A series of bases at varying ranges will provide joint force air commanders with options to disperse operations to bases appropriate to the level of the threat. **New bases (and existing forward bases) should be equipped with hardened aircraft shelters and other defensive, deception, and decoy systems.**

Trainers

The T-X program referenced earlier is critical to a rapid retirement of the very old T-38C, an aircraft that no longer meets the needs of pilots transitioning to 4th and 5th generation aircraft. **After low rate initial production, accelerate T-X to retire the T-38C faster than planned and to position the production line for F/T-X co-production.**

By 2030, the T-1 trainer's retirement will be imminent. The T-1 is a small business jet heavily adapted to train mobility pilots. **MITRE recommends retiring the T-1 and to not recapitalize it with a similar aircraft.** Move from the current Specialized Undergraduate Pilot Training (SUPT) program back to the Undergraduate Pilot Training (UPT) program. As it did for over 30 years prior to the introduction of SUPT in the mid 1990s, UPT will train a more universally assignable pilot with the T-6 and T-X, and this provides needed flexibility for the smaller size of the Air Force.

As a modern aircraft with systems oriented towards 5th generation training, the T-X and its armed relative, the F/T-X are ideally suited for economical adjacent missions such as adversary air and companion training for high cost fighters and bombers, not to mention rich collaboration with allies and partners.

Strategic Airlift

Intertheater airlift capacity with the C-5M and C-17 fleets will be stable through 2030, however C-17 retirements will begin in the early 2030s. With the closing of the C-17 production line in 2015, strategic airlift is the only critical U.S. airpower capability that is neither in or near production. **To avoid a rapid decline in strategic airlift capacity in the mid 2030s, new production (or a service life extension program) must be in place by 2030.**

Special Mission Aircraft

Special mission aircraft include Command and Control (C2), Air Battle Management (ABM), Intelligence/Surveillance/Reconnaissance (ISR), communications, and electronic attack. There are a variety of these aircraft with up to approximately 30 aircraft of each specific type. Many of these aircraft are quite old, having been built on the C-135 or C-130 platforms. In an A2/AD environment, these aircraft are at peril at increasingly long standoff ranges. As these aircraft reach the end of their service lives, there is an opportunity to decide whether a penetrating capability is required via stealth, attritable platforms, or space capabilities. If a new aircraft is needed, there is the opportunity to avoid the inefficient small fleets that characterize these missions.

Air Force UAVs (MQ-9 and E/RQ-4B) were included in the analysis, and while newer than many other special mission aircraft, they have similar survivability-vs-standoff issues. Fortunately, the long endurance and operating radius of current UAVs did not pose a basing survivability problem in the scenarios MITRE examined.

Cost of MITRE Recommendations

Through 2030, MITRE recommends a slightly larger Air Force with associated larger expenses compared to the Air Force baseline. Through 2030, the cumulative total increase in acquisition cost is \$30.1B (FY19 dollars), the increase to raise mission capable rates for all aircraft to at least 80% is \$27.3B, and there are an additional \$3.1B in other enhancements for a total bill of \$60.6B through 2030. This represents a 10% increase over the Air Force's aircraft-only planning baseline of \$612.6B during the same period. These figures include offsets from savings resulting from the recommendations.

In terms of fighter, bomber, tanker, and trainer inventories, MITRE's recommended 2030 totals and the Air Force baseline are nearly identical, as is the ratio of 55-45 percent 4th-to-5th generation fighters.

The most important difference between MITRE's recommendation and the Air Force baseline is the larger number of bombers in the 2030 inventory, and the fact that they must be maintained at higher mission capable rates.

A second major difference between MITRE's recommendation and the Air Force baseline is the proportion of recapitalized fighters. The Air Force baseline in 2030 is 50-50 percent legacy to recap, and MITRE's recommendation is 37-63 percent, indicating a younger average age for the recommended fighter fleet. The difference is due primarily to the accelerated retirements of legacy fighters and procurement of the F-15NG and F/T-X.

This spending will provide a larger available bomber force, a 50-50 mix of largely recapitalized 5th and 4th generation fighters, and a new light fighter for Homeland Defense and foreign military sales. Tanker and strategic airlift will continue largely as currently programmed, except for the addition of equipment to adapt tankers for additional roles such as communications. Additionally, all possessed aircraft will maintain a minimum 80% mission capable rate and be more available to fly in our nation's defense. Higher aircraft availability has the same net effect for the force as purchasing additional aircraft.

Conclusion: Conventional Deterrence

The tight coupling between basing, modern threats, aircraft capabilities, and the missions flown cannot be overstated. Improved basing options and a flexible balance of forward and rear operations with fighters, bombers, and tankers will improve and stabilize the correlation of forces in the Indo-Pacific, and reduce risk should tensions rise. As the basing and inventory investments recommended here are realized, the Air Force must concurrently revise and thoroughly exercise concepts of operations to tie the pieces together and smoothly interoperate with our allies and partners. These activities will ultimately deter conflict, yet prepare the U.S. to win decisively should conflict occur.