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Resilient Reach: Redesigning Aerial Refueling for Contested Global Operations

TIMOTHY A. WALTON AND SHANE DENNIN
CENTER FOR DEFENSE CONCEPTS AND TECHNOLOGY, HUDSON INSTITUTE



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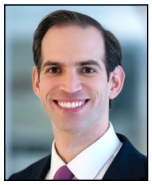
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This work builds on and draws material from previous and forthcoming reports coauthored by Timothy A. Walton, specifically *Resilient Aerial Refueling: Safeguarding the US Military's Global Reach* with Bryan Clark, *Flipping the Script: Redesigning the US Air Force for Decisive Advantage* with Dan Patt, and *Indo-Pacific Infrastructure and Logistics* (working title) with Shane Dennin and Sean Maxfield.[1]

TABLE OF CONTENTS

Executive Summary 9

Introduction 23

1. The Demand for Aerial Refueling 29

2. Problems Facing the Aerial Refueling Force 33

3. Surface Architecture and Mission Systems Improvements 41

4. Assessing Tanker Aircraft Options 51

5. Evaluating Tanker Performance Under Attack 69

6. Necessary Attributes of Future Tankers 81

7. Implementing an Effective and Resilient Aerial Refueling Force 85

8. Recommendations, Counterarguments, and Conclusion 97

Abbreviations 101

Endnotes 103



EXECUTIVE SUMMARY

Key Findings

1. Aerial refueling is an unmatched United States military advantage, but it currently depends on vulnerable forward bases and medium-range tankers that could be neutralized. Suppression of this critical capability could collapse US air operations and heavily contribute to US defeat in a war against the People's Republic of China (PRC).

2. To generate a force ready for contested global operations, the US Air Force and Department of War (DoW) can transform its aerial refueling architecture within planned budget levels by:

   - **Boosting the resilience of its most important tanker airfields**
   - **Incorporating adaptive mission systems on current tankers** to increase their effectiveness and survivability and unlock options for future tankers
   - **Fielding a medium-sized, long-range, high-offload tanker capable of flying a modest distance into contested airspace**, such as a Medium-sized Blended Wing Body (Medium BWB) tanker

Although the medium-range KC-46A has performed well in recent operations, our analysis finds that it lacks the range, offload, and survivability needed to sustain large-scale refueling across the vast Indo-Pacific in a conflict with the PRC—even when force extending. The slightly longer-range A330 MRTT+ faces similar constraints. Reduced signature shuttle tanking designs we modeled could provide a potent capability to refuel in contested airspace, thus improving the tactical performance and efficiency of a small number of

Photo: A US Air Force KC-135 Stratotanker refuels a C-5M Super Galaxy aircraft during a refueling operation over Evansville, Indiana, on July 24, 2025. (US Air National Guard)

supported force packages. However, they would face limitations operating at large scales, and their operations would depend on vulnerable parent tankers such as the KC-46A.

In contrast, aerodynamically efficient Medium BWBs could carry large fuel loads over long distances and could be equipped with robust self-defense suites to fly a modest distance into contested airspace. Moreover, given its medium size, lighter weight, and refueling-only design, a Medium BWB could cost less to procure and operate than larger, multi-role tankers such as the KC-46A.

3. Compared to 250 KC-46As, acquiring and operating 250 Medium BWB tankers could:
   - Refuel more than twice as many force packages or refuel force packages more than twice as far
   - Deploy forces across the Pacific more than twice as fast
   - Sustain large-scale, protracted operations under attack
   - Cost $15.5 billion less over 30 years and could be fielded with either additional funding or within planned annual funding levels, including in a budget-neutral manner that reduces KC-46A Tanker Production Extension procurement to fund Medium BWB development

The resulting architecture's abundance of aerial refueling would unleash the full lethality and optionality of the joint force, enable new standoff and penetrating concepts of employment, and assure US global reach, regardless of enemy attack. The Air Force and DoW can achieve a redesigned aerial refueling architecture that deters and wins.

Summary

Aerial refueling is essential to US military strategy. It supports strategic deterrence, defense of the homeland, and power projection. This competitive advantage, principally provided by the US Air Force, guards the country and allows a force predominantly based in the contiguous United States to rapidly deploy and fight effectively abroad. As a result, it is relentlessly employed in peacetime, and even more during the ongoing conflict with Iran, with over 200 tankers currently deployed to sustain operations.[2]

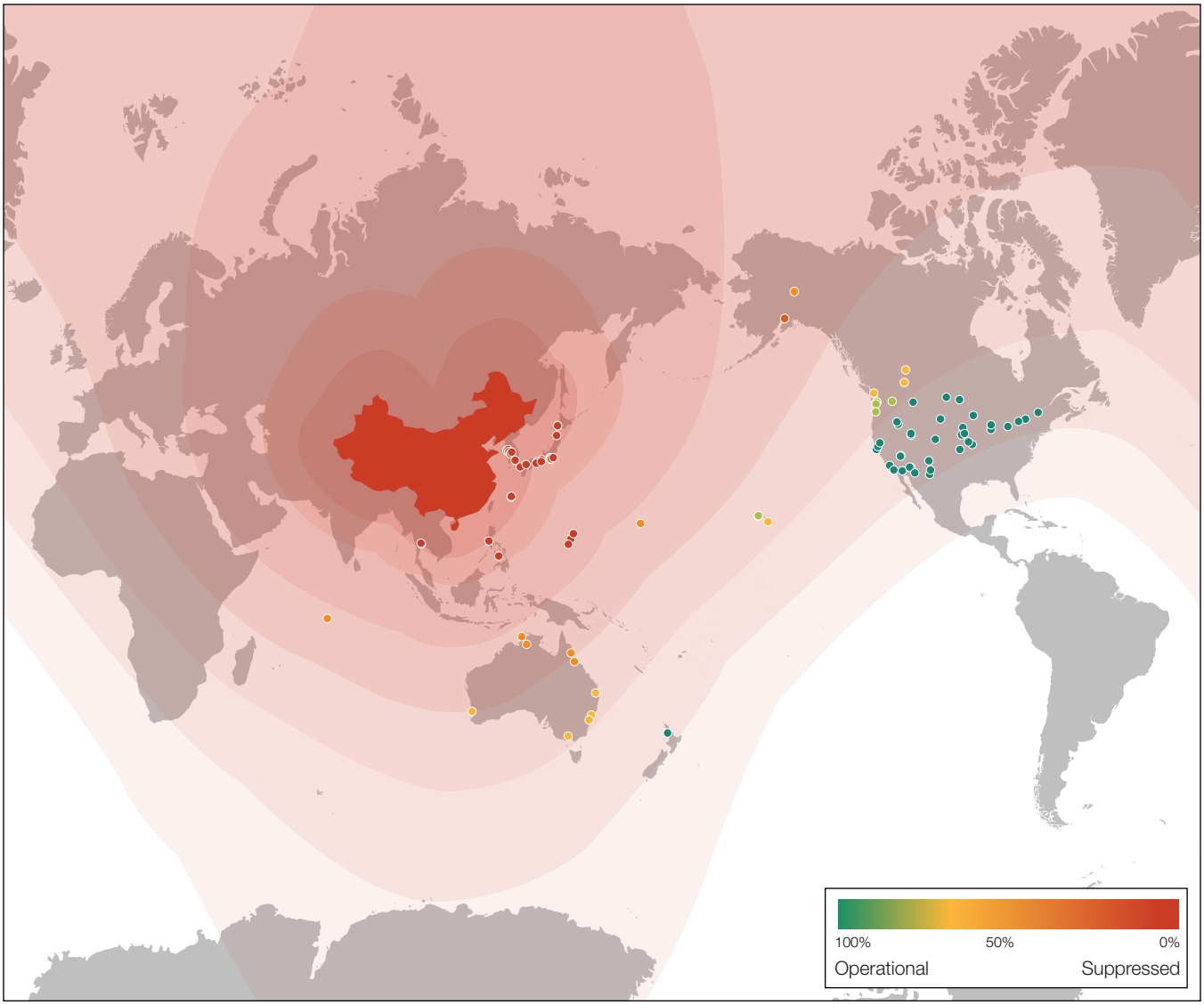
However, the US aerial refueling force has acute problems. Despite the introduction of the KC-46A tanker, the overall fleet is old, with an average age of over 50 years, and the Air Force projects some KC-135 tankers will approach the century mark before retirement. Consequently, operations and support costs continue to rise, while operational readiness declines.[3]

Even more concerning, the force is ill-suited for potential large-scale conflict against adversaries, in particular the PRC. Historically, aerial refueling aircraft operated from sanctuary on the ground and in the air. However, as Iran's 2026 attacks on Prince Sultan Air Base demonstrated, tankers can be targeted on the ramp.

The ability of the People's Liberation Army (PLA) to attack airfields and aircraft at them greatly exceeds the range, sophistication, and quantity of Iranian systems. It can deliver thousands of munitions per day against targets near the PRC, and as seen in figure ES.1, our analysis concludes that by 2035 the PLA could potentially suppress large-scale, sustained tanker operations from forward airfields in the Western Pacific. In practice, US and allied forces would likely adopt approaches that thin the level of threats and ensure continued tanker operations from some of these forward airfields in the First and Second Island Chains and continental Asia. However, widespread suppression of the forward and many of the intermediate airfields (in Diego Garcia, northern Australia, the Central Pacific, and Alaska) that tankers normally rely on would hobble the US military's ability to conduct a range of critical operations.

To reduce the density of threats on the ground, tankers could operate from distant airfields, but medium-range KC-135 and KC-46A tankers are unable to operate from distant airfields without force extension, in which one tanker refuels one or more other tankers to increase their range or endurance, which burns more tanker fuel and slashes effective capacity.[5] Current tankers are also vulnerable in the air, which could force them to stand

Figure ES.1. Operational Status of Airfields for Sustained Tanker Operations after One Week of Notional 2035 Conflict with PRC



Note: Figure depicts the mean result of 100,000 simulations of PLA attacks against airfields, and it accounts for estimated PLA threats, friendly defenses, and airfield characteristics.[4] It provides a conditional risk estimate of the operational status of airfields, rather than providing a prediction of the individual status of an airfield.

Source: Authors.

off so far from threats that their supported receiver aircraft must devote more of their fuel transiting to and from tankers and have little-to-no time on station to conduct operations.

Without effective aerial refueling, US forces could be severely constrained in a conflict. They could lose the ability to pulse power with bombers, dynamically operate fighters at scale, and

deploy forces and supplies with mobility aircraft. In short, unless the DoW fields a resilient aerial refueling architecture, the effectiveness of its air forces will be suppressed, and the United States could lose a war against China.

Transforming the Aerial Refueling Architecture

In response, the aerial refueling architecture should pursue three lines of effort to transform:

1. Boost the resilience of its surface infrastructure
2. Incorporate adaptive mission systems
3. Field a new type of tanker

Boost Surface Infrastructure Resilience

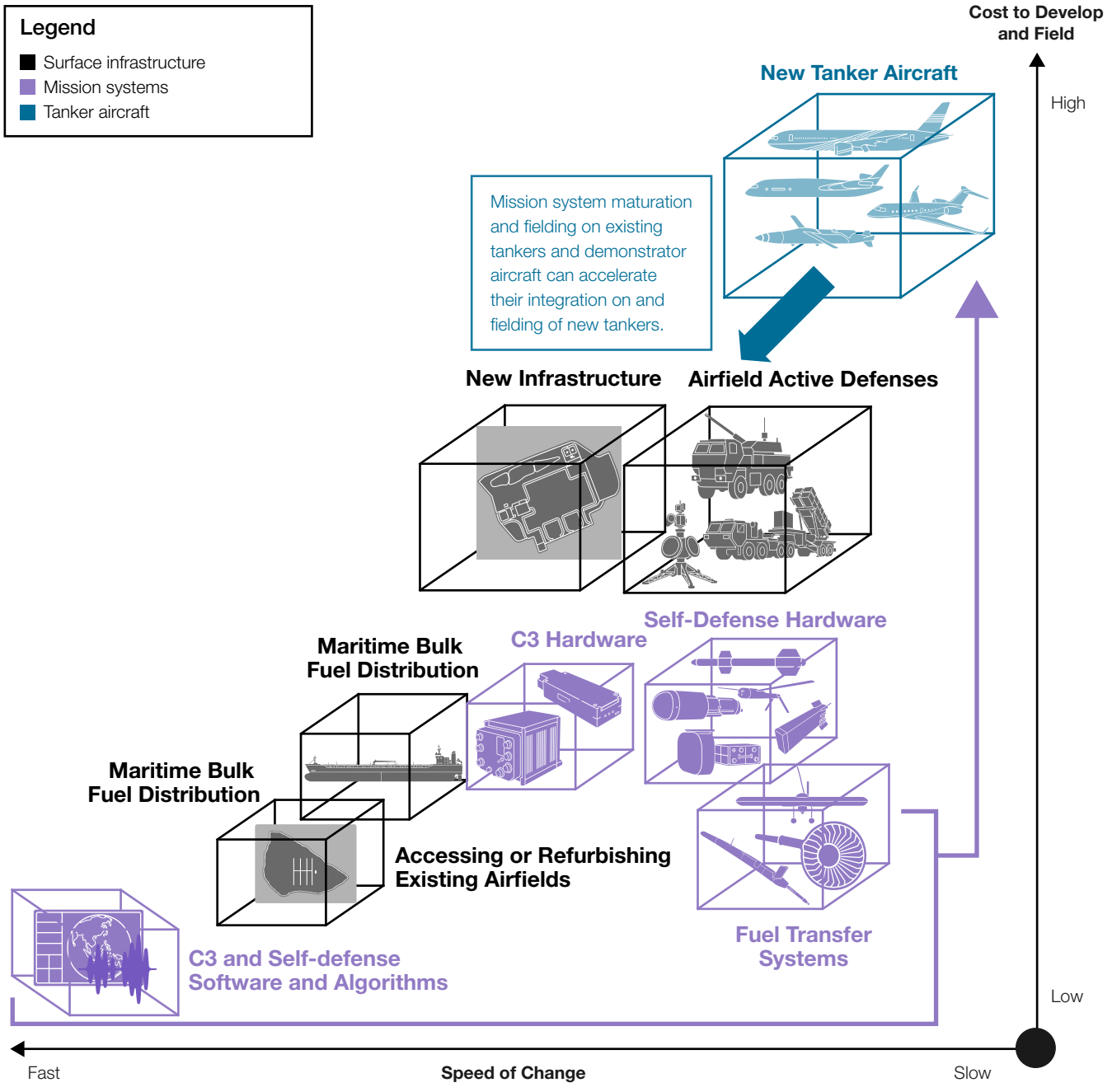
Aerial refueling surface infrastructure is the "network of airfields, maintenance facilities, and bulk fuel storage and distribution facilities and systems necessary to enable tanker operations."[6] "Enhancing the capacity and resilience of its surface architecture should be a top priority for the US Air Force—even if it comes at the cost of tanker procurement—because it will yield a greater increase in the number of employable tankers" and receiver aircraft supported.[7] To strengthen DoW's aerial refueling surface architecture, the department should first pursue access to more airfields, including large commercial ones, and nurture its invaluable relationships with North Atlantic Treaty Organization (NATO) and other allies that provide access to tanker airfields. Second, it should improve bulk fuel storage and distribution by constructing lower-capacity hardened fuel stores rather than higher-capacity but vulnerable aboveground storage tanks, fielding airfield and over-the-shore fuel distribution systems, and securing access to more maritime tankers, including by levying higher working capital fund rates to fund bulk fuel resilience initiatives. Lastly, it should better defend airfields. As witnessed at Prince Sultan Air Base, dispersion alone is insufficient to avoid attack in an era of persistent surveillance and precision targeting. To do so, the Air Force will need to fund passive defenses (such as personnel and equipment bunkers, reconstitution equipment and units, redundant capabilities, the aforementioned fuel infrastructure hardening, more hardened large aircraft shelters, and tanker decoys) and active counter–command, control, communications, computing, cyber, intelligence, surveillance, reconnaissance, and targeting (C5ISRT) and air and missile defenses to defeat threats.

Incorporate Adaptive Mission Systems

Mission systems are the hardware and software that allow aircraft to perform their operational roles, as distinct from aircraft airframe and propulsion systems. Current tankers lack an adequate ability to communicate in a secure manner, have situational awareness of friendly or other forces, or defend themselves against threats. This lack of situational awareness may have contributed to a deadly midair collision between two KC-135s in 2026.[8] To address glaring gaps in tanker survivability and increase effectiveness, the Air Force should prioritize necessary command, control, and communications (C3), self-defense, fuel transfer, and automation and autonomy improvements.

Much like in the Next Generation Air Dominance team of systems, the rapid evolution of mission systems will require a software ecosystem that can make investments extensible across aircraft types and integrate different capabilities and program elements within not only the mobility enterprise, but also the broader Air Force, joint force, and allies and partners.[9] By creating a software-defined architecture upfront and separating the development and maturation of some mission systems from tanker aircraft, the Air Force could more rapidly field different sets of capabilities to current and programmed tankers, adopt an adaptive approach to aerial refueling operations, and mature systems on existing tankers and demonstrator aircraft that unlock capabilities for the next generation of tanker aircraft. New C3, compact boom, and autonomy kits could also potentially allow the conversion of some KC-135s into remotely controlled tankers or some commercial aircraft into refuelers, creating a latent, rapidly scalable war reserve of tankers. As

Figure ES.2. Investments in Surface Infrastructure and Mission Systems Enhance the Effectiveness and Survivability of Current Tankers, Buy Down Risk, and Unlock Future Options



Source: Authors, inspired by figure 9 in Bryan Clark and Dan Patt, *Building a Team for Next Generation Air Dominance* (Hudson Institute, 2022), 19, https://www.hudson.org/national-security-defense/building-a-team-for-next-generation-air-dominance.

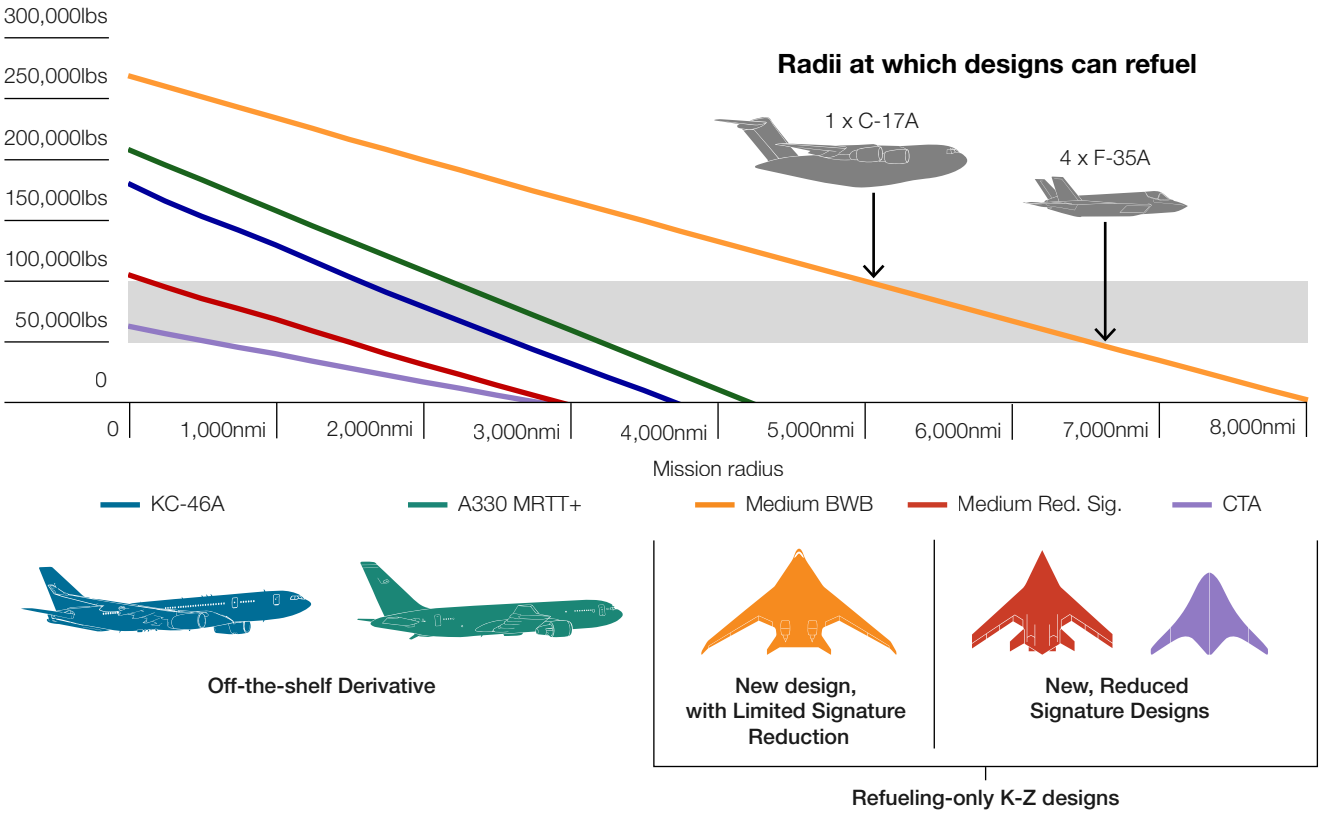
depicted in figure ES.2, many improvements in surface infrastructure and mission systems could be more rapidly and economically fielded compared to new tanker aircraft, and mission system maturation and fielding on existing tankers and demonstrator aircraft can reduce the time and cost required to field new tankers.

Field a New Type of Tanker

Improvements to aerial refueling surface infrastructure and mission systems can enhance the ability of the current and programmed tanker fleet to support operations in challenging scenarios, including a potential conflict with China. But they are not enough.

The KC-135 fleet urgently needs replacement, and the characteristics of current medium-range KC-135 and KC-46A tankers make them vulnerable on the ramp and in the air to enemy attack and incapable of providing sufficient capacity in direct delivery (in which a tanker directly delivers fuel to receiver aircraft) or force extension to support large-scale, long-range operations—especially as the military services

Figure ES.3. Representative Tanker Types and Their Estimated Fuel Offload at Radius When Taking Off with a 100 Percent Fuel Load



Note: Unless otherwise noted, our modeling assumes operation from dry and level runways that are at International Standard Atmosphere +15° Celsius (86° Fahrenheit) and 500 ft pressure altitude, and it uses the same mission profile, with offload taking one hour and one hour of reserve (45-minute Max Endurance Loiter at 10,000 ft and 15 minutes of Contingency Fuel). Assessments also dynamically account for airfield length, pavement firmness, ramp space, and fuel stores in assessing suitability for tanker aircraft and tankers' takeoff fuel load.

Source: Authors, with the Medium BWB image based on the Boeing ERA-009H1 concept and the Medium Reduced Signature image based on a Boeing "stealthy BWB."[12]

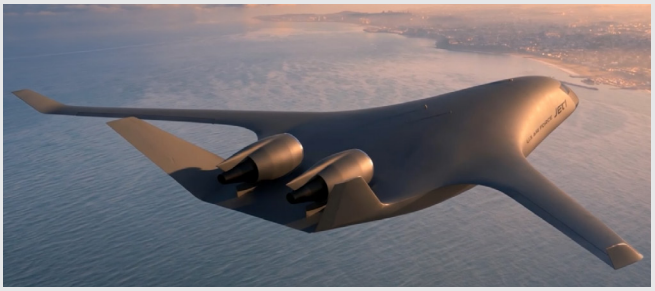
What Are Blended Wing Body (BWB) Aircraft?

BWB aircraft merge the fuselage and wings into a single lifting shape, reducing drag compared with most large aircraft that consist of a tube with wings attached.[13] Distinct from tube-and-wing and flying wing aircraft, the design was first developed in 1989 by Robert Liebeck at McDonnell Douglas. Since then, multiple firms have created BWB concepts and flown sub-scale prototypes, including established firms such as Airbus, Boeing (whose Medium BWB design is shown in figure ES.3), Bombardier, Lockheed Martin, and Northrop Grumman, and startups JetZero and Natilus.

In 2023 the US Air Force awarded JetZero, in partnership with Northrop Grumman, a contract to build and test a full-scale BWB demonstrator (shown in figure ES.4) that is scheduled to fly by the end of 2027. There is considerable commercial interest in passenger and freighter BWB aircraft since they could reduce fuel burn and significantly improve seat and cargo-mile economic performance. More aircraft production and new aircraft manufacturers could increase competition and help address burgeoning commercial demand for aircraft that has outstripped the supply provided by incumbents, chiefly Airbus, Boeing, and Embraer. Moreover, the maturation of aircraft design tools and composites manufacturing has improved the economic viability of scaled BWB production.

The PRC has also taken significant interest in BWBs. The Commercial Aircraft Corporation of China (COMAC), which the US DoW has recognized as a Chinese military company, is manufacturing tube-and-wing commercial aircraft.[14] It is also pursuing BWB concepts (as shown in figure ES.5) for potential commercial introduction in the 2040s. If the United States does not take the lead in applying BWB designs for commercial and defense applications, the PRC and other countries will likely do so.

Figure ES.4. Computer-Generated Image of JetZero's US Air Force BWB Demonstrator



Source: JetZero.

Figure ES.5 COMAC and Northwestern Polytechnical University–Developed Subscale BWB Commercial Airliner Flown in 2023



Source: Graham Warwick, "China Flies Subscale Blended Wing Body Airliner Concept," *Aviation Week,* February 3, 2023, https://aviationweek.com/air-transport/china-flies-subscale-blended-wing-body-airliner-concept.

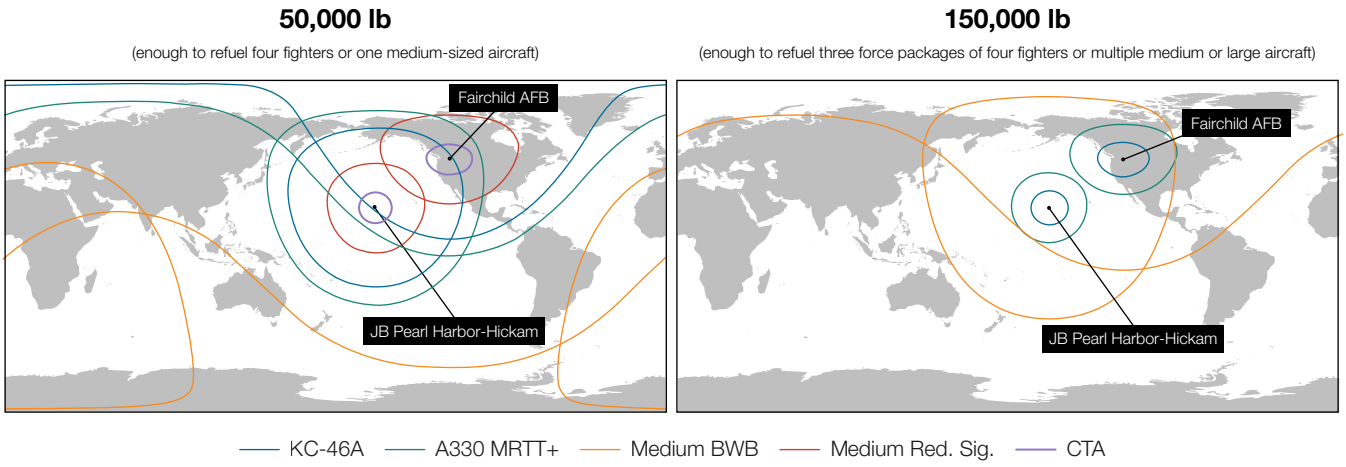
embrace more distribution, dynamism, and tempo.[10] Our simulations of potential conflict with the PRC conclude that absent change, US and allied forces could be defeated, as US and allied tanker-relevant airfields (and aircraft on them) could face heavy, repeated PLA attacks—even after distribution and dispersal—and 40 percent of potential receiver refuelings could be unmet.[11]

Accordingly, the Air Force should consider whether it should buy more KC-46A (such as the currently planned 75 or more KC-46A Tanker Production Extension aircraft) or pursue another design.

To identify the necessary attributes for future tankers, we evaluated the representative tanker types shown in figure ES.3. Using modeling and simulation tools, we assessed each aircraft's level of airfield access and performance attributes, ability to support relevant mission vignettes set in different combatant commands, ability to sustain theater-level operations under attack, and ability to deploy forces. Moreover, we employed the aircraft in different ways: direct delivery, force extension, shuttle tanking (parent tankers deliver fuel to child tankers, which shuttle back and forth from parent tankers to receiver aircraft), and force extended-shuttle tanking.

The largest differentiators among the designs are the amount of fuel that they can offload at radius (shown in figure ES.3) and whether they can transport cargo or personnel. The Medium-sized Reduced Signature (hereafter referred to as Medium Reduced Signature) and Collaborative Tanker Aircraft (CTA) concept designs are refueling-only aircraft optimized to shuttle tank from parent tankers such as the KC-46A, and they can provide 50,000 lb of fuel (enough to refuel once a force package of four fighters or one medium-sized aircraft) at a short-to-moderate distance. The Boeing KC-46A and Airbus A330 Multi Role Tanker Transport (MRTT)+ can transport cargo, passengers, and aeromedical patients, and refuel aircraft, specifically multiple fighter packages or one large aircraft, such as a C-17A transport requiring 100,000 lb of fuel, at short-to-moderate distances. In contrast, the Medium BWB is a long-range, high-offload dedicated tanker. With its aerodynamically efficient design and large fuel ca-

Figure ES.6. Radius of Tankers Offloading Fuel Over an Hour



Source: Authors.

Table ES.1. Summary of Performance of Tanker Options

MODELING AND SIMULATION PERFORMANCE (COLORED FONT COMPARES OTHER TANKERS AND THE KC-46A)		KC-46A	A330 MRTT+	MEDIUM BWB	MEDIUM RED. SIG.	CTA
Average relative percentage of tankers required to support mission vignettes in Pacific, Northern, European, and Central Commands[1]		100%	87% **0.9x**	70% **0.7x**	154% **1.6x**	213% **2.1x**
Total tanker and F-35A fighter cost to sustain 5 Combat Air Patrols in the Western Pacific from airfields >2,000 nmi from PRC coast (billions of FY 2027 dollars)[2]		$110	$75 **0.7x**	$30 **0.3x**	$51 **0.5x**	$66 **0.6x**
Number of airfields from which can sustainably generate 5 continuous Air Refueling Control Points (ARCPs) in the Philippine Sea in a conflict with the PRC[3]	50,000 lb/hr ARCPs	31	37 **1.2x**	90 **2.9x**	19 **0.6x**	24 **0.8x**
	100,000 lb/hr ARCPs	19	21 **1.1x**	69 **3.6x**	**0**	**0**
Days required to deploy an equivalent joint force in a conflict with the PRC[4]		30	27 **0.9x**	13 **0.4x**	N/A	N/A
Number of continuous ARCPs can sustain in the Philippine Sea amidst PRC attack over a month[5]	50,000 lb/hr ARCPs	7	8 **1.1x**	16 **2.3x**	3 **0.4x**	3 **0.4x**
	100,000 lb/hr ARCPs	1	2 **2.0x**	5 **5.0x**	**0**	**0**

Note: Unless otherwise noted, modeling and simulation employ direct delivery, force extension, and shuttle tanking where appropriate. Table values are rounded, and additional information on the table can be found in the endnote.[16]

Source: Authors.

pacity, it can refuel more than twice as many force packages or refuel force packages more than twice as far as the KC-46A. At longer ranges and higher offloads, the Medium BWB can deliver up to five times as many operationally relevant increments of fuel as the KC-46A.[15] This enables it to effectively operate over broad areas, including from airfields less vulnerable to attack in the contiguous United States, as seen in figure ES.6. Table ES.1 summarizes the performance of the different tanker types across some of the analyses we conducted.

Although currently available, the KC-46A and A330 MRTT+ do not provide the most important necessary attributes for the next type of future tanker. Given their medium ranges, they must force extend to operate at acceptable levels of risk from intermediate and distant airfields. And when they force extend, they can only support a moderate number of forces for a limited period of time, which would hinder the joint force's ability to operate with distribution, scale, and tempo, as well as protract a conflict. These limitations are most evident in Indo-Pacific scenarios with the PRC, but they can also be seen in vignettes in other

regions, such as extended support to air defense coverage in the Arctic, refueling strategic deterrence missions, and enabling the trans-oceanic deployment or employment of large force packages to Europe or the Middle East.

Moreover, although these aircraft could adopt enhanced C3 and self-defense systems to fly a bit closer to threats, many of these potential systems would likely impose weight and drag penalties that exacerbate offload-at-range limitations, and the aircraft designs will constrain the size, weight, power, and cooling of advanced self-defense systems. Consequently, over time these designs will likely face even greater challenges approaching contested areas to refuel receiver aircraft at an appropriate level of risk.

Reduced signature shuttle tanking designs, such as the Medium Reduced Signature and CTA concepts we examined, could penetrate much deeper into contested airspace and greatly improve the tactical performance and efficiency of a small number of supported force packages. However, designs reliant on shuttle tanking fail to address the fundamental range problem facing the tanker fleet. Shuttle tanking operations would remain highly vulnerable to attacks on the forward and intermediate airfields from which parent tankers such as the KC-46A would fly. And if parent KC-46As introduced even more complexity and fragility into shuttle tanking by force-extending to support child tankers, then the available tanker capacity to support these and other operations throughout the theater would be even less.

Adversary threats and friendly demands require aerial refueling solutions that generate greater optionality vice enhanced optimality for current approaches. Rather than pursuing incremental improvements in performance, such as supporting a few more air refueling control points (ARCPs) or clawing back a bit more access, future aerial refueling platforms should generate a massive increase in the optionality, lethality, and resilience of the joint force that enables new, more effective operational approaches.

A medium-sized, long-range, high-offload tanker such as a Medium BWB provides these necessary advantages. It could be significantly cheaper than the KC-46A, requiring fewer tankers, burning less fuel, and costing less to field and operate across missions. Given its new design and size, weight, power, and cooling margins, it could be equipped with a robust, integrated defensive suite (and, to a minor degree, passive signature management) that exceeds the performance of retrofits to current tankers and enables it to fly closer to threats. Operationally, it could perform relevant missions from more than twice as many airfields, since it could effectively operate from forward, intermediate, and distant airfields. This would provide US commanders with more options and would make their operations more difficult for adversaries to counter. The Medium BWB could also refuel more than twice as many force packages or refuel force packages more than twice as far, effectively sustain large-scale protracted operations under attack, enable the deployment of forces and supplies across the Pacific more than twice as fast, and most improve campaign success and Red:Blue aircraft loss ratios in a 2035 Taiwan invasion scenario.

In summary, examining mission and theater demands reveals necessary attributes for future tankers. They should be able to:

1. *Deliver high offloads of fuel at long ranges*. This ability would reduce susceptibility to attack on the ground by operating from intermediate and distant airfields. It would also enable large-scale and rapid bomber and mobility missions and other force deployments, and it would generate more endurance and maneuverability for a broad range of receiver aircraft, allowing them to operate in a more dynamic and distributed manner.
2. *Access and operate from forward, intermediate, and distant airfields* to enable operational flexibility and challenge adversary targeting. This entails not only long-range but also reasonable takeoff field lengths and pavement strength requirements to access airfields and moderate size to efficiently use valuable and contested ramp space.

3. *Stand-in a modest distance (as opposed to standing off from or penetrating deep) into contested air environments* to reduce the number of fighters and other receivers required to conduct operations, and tankers should have an appropriate level of survivability in that contested airspace.
4. *Exhibit high operational availability rates, limited ground support equipment requirements, and fast turn and scramble times* to maximize fleet usage and flexibility and minimize exposure and vulnerability to attack on the ground.

The medium-range KC-46A has performed well in contemporary operations and would play an important role in any conflict. But it is not well-suited for long-range refueling in a large-scale, sustained conflict with the PRC in the vast Indo-Pacific—even when force extending—and faces challenges in other scenarios as well.[17] Nor is the slightly longer-range A330 MRTT+ or designs that rely on large-scale shuttle tanking. Instead, the Air Force requires a medium-sized, long-range, high-offload tanker capable of flying a modest distance into contested air environments.

But the temptation to simply continue buying more incumbent KC-46A will be strong. With the Air Force planning on fielding at least 185 KC-46A and possibly 260 (more than half of its 502-tanker requirement) or more, it may consider filling out the rest of its force with KC-46A outfitted with improved mission systems, thus achieving fleetwide economies and avoiding the budgetary and schedule risks associated with a new development program. It should resist doing so. A tanker fleet of KC-46As alone is insufficient to win in conflicts that require long-range, contested refueling operations.[18]

Instead, the Air Force can pursue alternative plans that provide far more capability and capacity at a lower cost and fit within projected resource constraints. For example, assuming conservative research, development, test, and evaluation (RDTE), cost-per-pound, and mission system costs, for the same RDTE and procurement cost to buy 250 more improved KC-46A, the Air Force could likely buy 290 longer-range, higher-offload, lower-cost Medium BWB tankers.

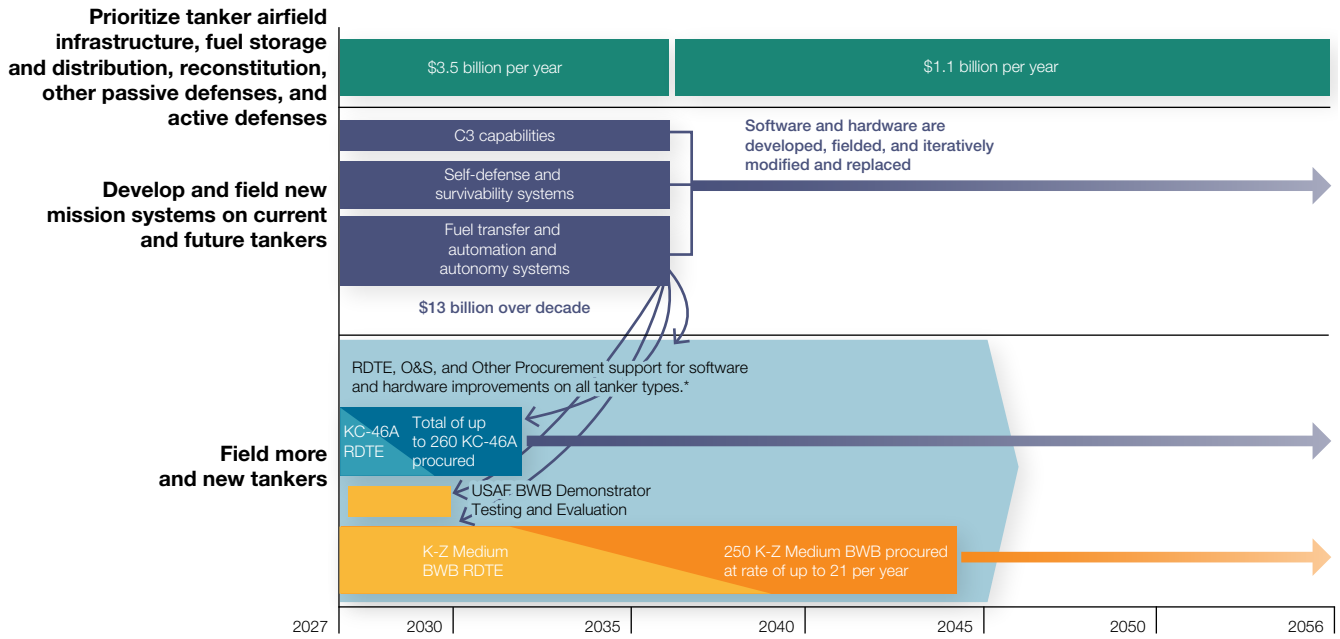
Another risk for the Air Force is that, due to competing fiscal priorities, policymakers might delay a future tanker program or assume that longer-range combat aircraft and weapons obviate the need for a new tanker. However, it is well past time to replace the 1950s-era KC-135 fleet given the structural and reliability concerns it faces. Further delays would compel the Air Force to incur more, increasingly severe operational risk and force it to continue buying range-limited KC-46As to avoid a break in the delivery of new aircraft or fund another, even more expensive KC-135 service life extension to prolong their operation past the century mark. Furthermore, US Air Force and Navy initiatives that extend the organic and weapons range of aircraft should be pursued, since they can increase the lethality and survivability of the force and reduce aerial refueling demands—especially in more-contested airspace. However, as the services plan to field more, longer-range bombers and fighters and adopt concepts and tactics with more distribution and dynamism, they urgently require the additional range and endurance provided by a long-range, high-offload tanker that can stand-in a modest distance, such as a Medium BWB.

Implementing an Effective and Resilient Aerial Refueling Architecture

To field an effective and resilient aerial refueling architecture, the Air Force can take a holistic approach that appropriately funds elements of the entire aerial refueling architecture and is achievable within plausible projected portfolio resources. As described in *Flipping the Script: Redesigning the US Air Force for Decisive Advantage*, our proposed plan could be pursued with additional resources or under a flat budget.[19]

As shown in figure ES.7, we propose that starting in Fiscal Year (FY) 2027, the Air Force and other parts of the DoW should prioritize military construction and other funding to enhance the

Figure ES.7. Summary of Proposed Aerial Refueling Architecture Plan



Note: *All KC-135s retired by 2046 (2+ years earlier)

Source: Authors.

capacity and resilience of its most important tanker airfields—especially intermediate and distant ones. The Air Force should also continue and increase funding for C3, self-defense, fuel transfer, and automation and autonomy mission systems for current and future tankers. These should be integrated by an adaptive and extensible software ecosystem.

In terms of aircraft, the Air Force should resolve ongoing deficiencies with the KC-46A, acquire a requisite number of KC-46A Tanker Production Extension aircraft, and direct FY 2027 funding to mature medium-sized, long-range, high-offload capacity tanker designs, such as Medium BWB. Then, assuming successful evaluation of its BWB demonstrator in 2027 and 2028, award in FY 2028 a development contract for a Medium BWB tanker. This approach would allow the testing of prototype aircraft before procurement awards starting in FY 2032 and rising to a rate of 21 per year, which is three more than currently planned for Tanker Production Extension KC-46As. If deemed necessary to hedge against maturity and schedule risk with its new tanker, the Air Force could be prepared to exercise the option to extend the procurement of KC-46A Tanker Production Extension aircraft (at either the same rate or a reduced rate) for another year or more as necessary.

Our proposed plan's yearly tanker costs would require additional RDTE outlays in the late 2020s and early 2030s, but its total RDTE, procurement, and operations and support (O&S) costs over 30 years could amount to $15.5 billion less than a plan that solely procured KC-46A.[20] This finding is robust to changes in costing assumptions: Medium BWB RDTE costs

could more than triple, average procurement unit costs (APUC) could increase by approximately 25 percent, or O&S costs could increase by about 21 percent before an all-KC-46A fleet would be more economical than a fleet that added 250 Medium BWB.

If 75 KC-46A Tanker Production Extension aircraft were procured, the resulting mixed fleet of 260 medium-range refueling-, cargo-, passenger-, and aeromedical-capable KC-46As and 250 long-range, high-offload dedicated refueling Medium BWBs would complement each other. It could refuel 1.6–2.8 times as many increments of fuel as an alternative fleet of 510 KC-46As, and it would provide approximately 14 percent more cargo capacity than the US Air Force's 2026 tanker force.[21] Together, the force could succeed in its most stressing scenarios, as well as sustainably execute other operations across the world.

Other variations on this plan are possible and may be desirable. For example, if budgetary limits constrained funding available for concurrent RDTE and procurement, the Air Force could reduce its KC-46A Tanker Production Extension buy to 49 vice 75 aircraft. The resulting fleet of 234 KC-46A (and 250 or more Medium BWB) would provide at least 63 percent more aerial refueling capacity and an equivalent level of cargo capacity as today's tanker fleet, and allow approximately $7.8 billion to be redirected toward Medium BWB RDTE and procurement, and other force demands such as surface infrastructure and mission system modernization. Similarly, if the Air Force found that it required a small fleet of reduced signature shuttle tankers, it could use savings from a slimmed KC-46A Tanker Production Extension buy (or foregoing it entirely) and redirect the funds to that program, in addition to the Medium BWB. Investments in a shuttle tanker should, however, be weighed against alternative investments in longer-range weapons and combat aircraft organic range, and a medium-sized, long-range, high-offload tanker such as a Medium BWB should be the Air Force's next and top mobility priority.

The Time to Transform Is Now

Aerial refueling is essential to US military operations and is in high demand across the world. But too often it is also the limiting factor on the distribution, pace, and lethality of US campaigns. Worse still, as the KC-135 fleet continues to age and as adversaries field ways to neutralize US aerial refueling on the ramp and in the air, this strategic advantage is increasingly a liability that could cause the United States to lose a war—especially against the PRC in the Indo-Pacific.

The Air Force and DoW have an opportunity to transform. By prioritizing across portfolios, it can, within planned budget levels, boost the resilience of its surface architecture, incorporate an adaptive ecosystem of mission systems that can raise force effectiveness and survivability as well as unlock options for future tankers, and field a new type of tanker. Medium-sized, long-range, high-offload tankers such as Medium BWB that could fly a modest distance closer to threats could not only cost less than simply buying more KC-46A, but more importantly could create an abundance of aerial refueling that unlocks new standoff and penetrating concepts of operation, enables more dynamic and lethal operations, and assures the global reach of US forces, regardless of enemy attack. Collectively, this force would provide far greater capacity and capability to address a range of demands, including the United States' most challenging scenarios, and unleash the full potential of the joint force to deter conflict or win if necessary.



INTRODUCTION

Aerial refueling is essential to United States military strategy. It supports strategic deterrence, defense of the homeland, and power projection. This competitive advantage, which is principally provided by the US Air Force, guards the country and allows a force predominantly based in the contiguous United States to rapidly deploy and fight effectively abroad. However, as Timothy A. Walton and Dan Patt argued in a previous Hudson Institute report, the People's Republic of China (PRC) poses a unique challenge:

> The US Air Force's traditional approach, involving expeditionary and serial power projection, is increasingly insolvent against the PRC for a variety of reasons: China can target in mass the gradual deployment of forces to the Indo-Pacific; forces are vulnerable at airfields once they arrive; the PRC could achieve its aims of aggression, such as invading Taiwan or seizing other allied territory, before US forces could roll back enemy defenses to attack the PRC's center of gravity; and if the conflict continued, the Air Force would struggle to replace its losses, much less grow in size.[22]

These weaknesses apply to the Air Force as a whole but are particularly acute in the aerial refueling tanker fleet. Despite the introduction of the KC-46A tanker, the overall fleet is old, with an

Photo: A US Air Force F-35A Lightning II approaches a KC-135 Stratotanker to conduct aerial refueling during a training flight over the Pacific Ocean on July 8, 2026. (US Air Force)

average age of over 50 years, and the Air Force projects some KC-135 tankers to approach the century mark before retirement. As a result, operations and support (O&S) costs continue to rise while operational readiness declines.

More importantly, however, the force is ill-suited for potential conflict against the PRC. Historically, aerial refueling aircraft operated from sanctuary on the ground and in the air. However, as Iran's attacks on Prince Sultan Air Base demonstrated, adversaries can target tankers on the ramp. The People's Liberation Army's (PLA) ability to attack airfields and aircraft at them dramatically exceeds the range, quality, and quantity of Iranian systems. To reduce the density of threats on the ground, tankers could operate from distant airfields, but KC-135 and KC-46A tankers lack the range to do so without force extension in which one tanker refuels one or more other tankers to increase their range or endurance. This method burns more tanker fuel and slashes effective capacity. Current tankers are also vulnerable in the air, which could force them to stand off so far from threats that their supported receiver aircraft must devote more of their fuel transiting to and from tankers and have little to no time on station to conduct operations.

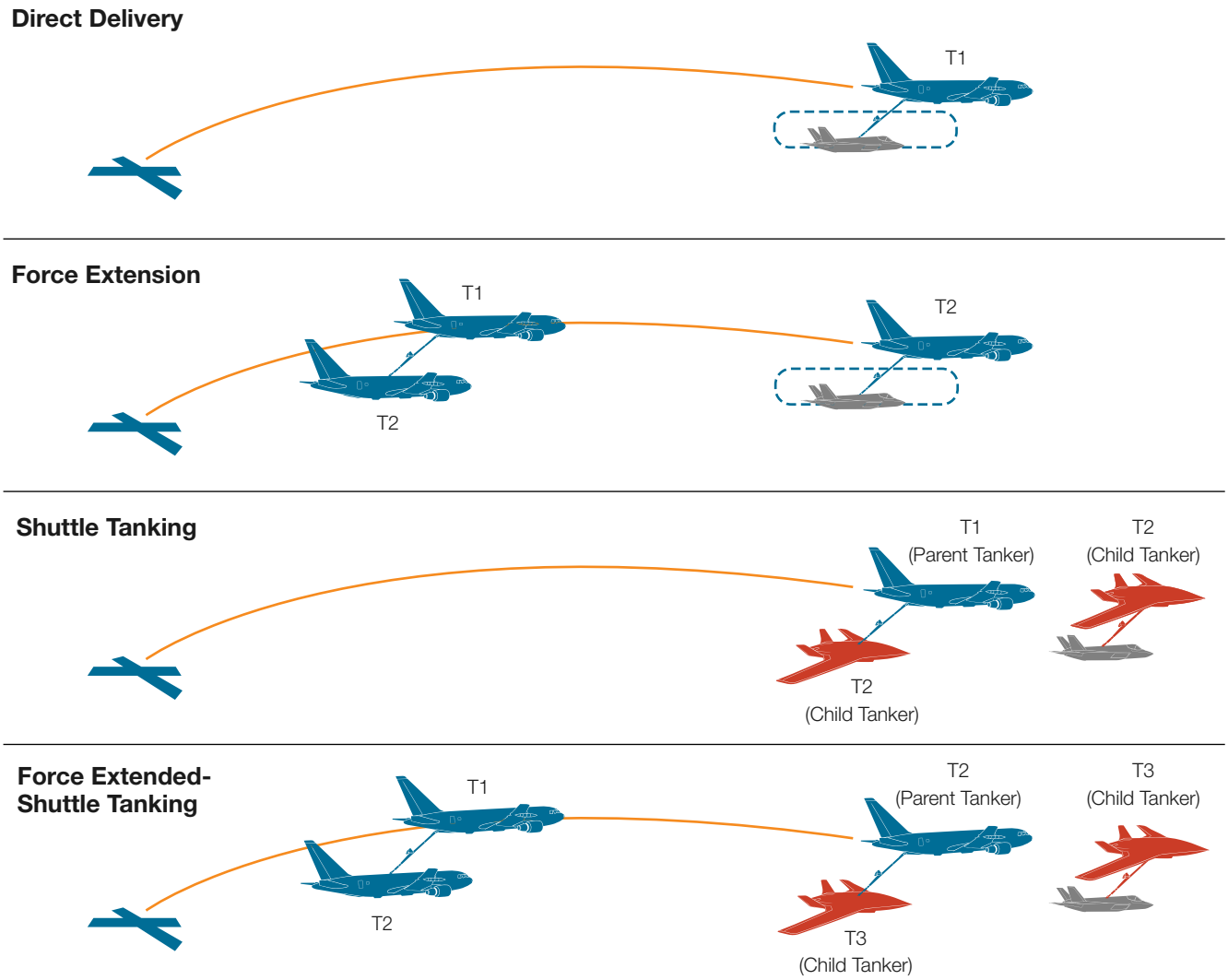
A lack of effective aerial refueling could cripple US forces in a conflict. They could lose the ability to pulse power with bombers, dynamically operate fighters at scale, and deploy forces and supplies with mobility aircraft. In short, unless the Department of War (DoW) fields a resilient aerial refueling architecture, logistical problems and opposing forces could suppress the capacity, capability, and optionality of its air forces, and the United States could lose a war against China.

Air Force leaders recognize this challenge and conducted an analysis of potential Next Generation Air Refueling System (NGAS) options and a succeeding Advanced Tanker Systems initiative. However, questions remain about whether a new type or types of tankers are necessary or whether more, improved, and differently operated KC-46As would suffice. And if the DoW pursued a new tanker type, what should it be: a reduced signature shuttle tanker or something else entirely?

In response, this study assessed the current and programmed US aerial refueling enterprise. The work builds on and draws from previous reports coauthored by Mr. Walton, specifically *Resilient Aerial Refueling: Safeguarding the US Military's Global Reach* with Bryan Clark and *Flipping the Script: Redesigning the US Air Force for Decisive Advantage* with Dr. Patt.[23] In addition to examining necessary changes to aerial refueling surface infrastructure and mission systems, it answers a key set of questions: What attributes should US Air Force aerial refueling tankers have? Does the US Air Force need a new type of aerial refueling tanker? If so, what attributes should it have? And how could it fund the new tanker type and other necessary surface infrastructure and mission system improvements? To do so, the study discusses evolving aerial refueling demands, including the effects of changes in Air Force and joint force structure and design. It assesses the performance and impact of existing and developmental tanker options on relevant vignettes and scenarios, and proposes how the Air Force could resource necessary investments.

To identify the attributes required of future tankers, we evaluated five representative tanker archetypes using modeling and simulation tools. We examined their performance and ability to support relevant mission vignettes across multiple combatant commands, sustain theater-level operations under attack, and deploy forces. Assessments considered the impact of potential adversary threats to airfields, to tankers on the ground, and to tankers in the air and their operations. Assessments also dynamically accounted for airfield length, pavement firmness, ramp space, fuel stores, and tankers' takeoff fuel load in assessing the ability of tankers to execute missions. Unless otherwise noted, our modeling assumes operation from dry and level runways that are at International Standard Atmosphere +15° Celsius (86° Fahr-

Figure I.1. Aerial Refueling Employment Concepts



Note: T = Tanker. To simplify the figure, force extension and shuttle tanking are depicted using two tankers. This project's analyses considered force extension and shuttle tanking with one and multiple other tankers, as well as force extension with homogenous and heterogeneous tanker types. Tanker images are Boeing KC-46A and Boeing "stealthy BWB."[24]

Source: Authors.

enheit) and 500 ft Pressure Altitude, and it uses the same mission profile, with offload taking one hour and one hour of reserve (45-minute Max Endurance Loiter at 10,000 ft and 15 minutes of Contingency Fuel).

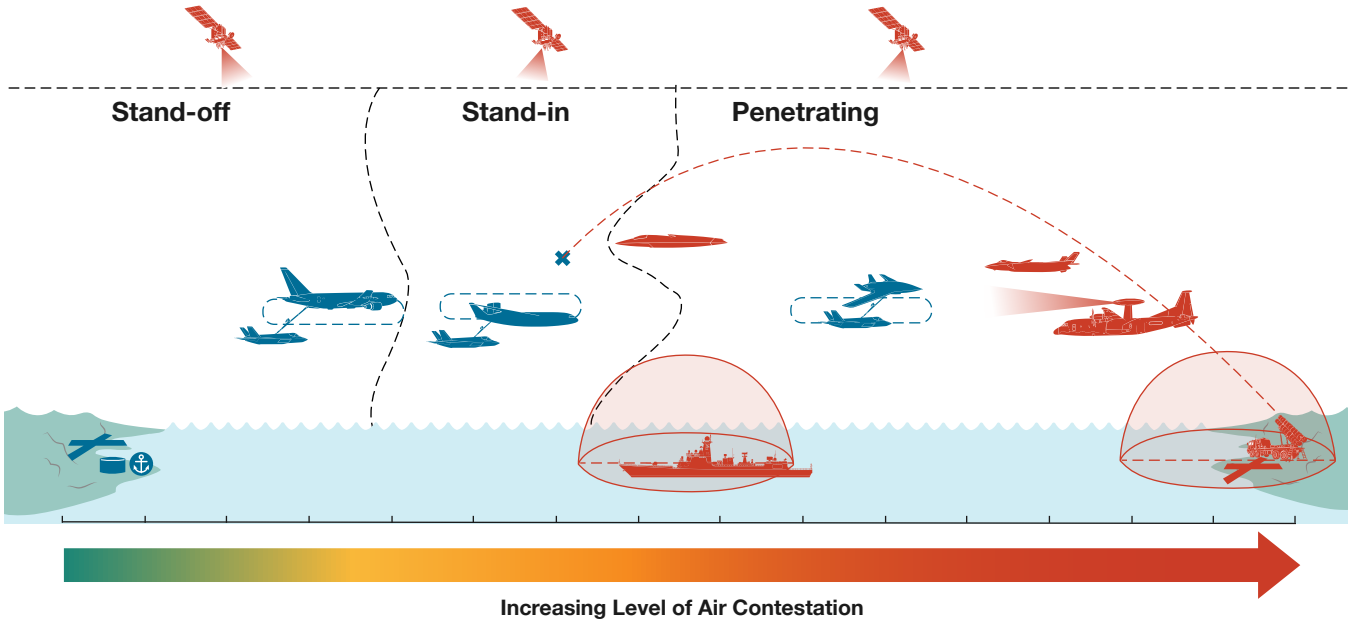
In these assessments, we employed the aircraft in different ways (depicted in Figure I.1): direct delivery (in which a tanker directly delivers fuel to receiver aircraft), force extension (in which one tanker refuels one or more other tankers to increase

their range or endurance), shuttle tanking (parent tankers deliver fuel to child tankers, which shuttle back and forth from parent tankers to receiver aircraft), and force extended-shuttle tanking. Within this report, fuel consolidation is considered a subset of force extension.

Furthermore, the assessments operated tanker designs at both fixed and parametrically varied stand-back distances from counter-air threats. This report uses a lexicon to describe, in general terms, how close to enemy threats tankers could routinely refuel receiver aircraft in contested scenarios at an acceptable level of risk. As shown in Figure I.2, standoff tankers remain outside the weapons engagement zones of enemy threats, generally operating in uncontested or lightly contested airspace; stand-in tankers could, when necessary, enter a modest distance into moderately contested airspace and defeat occasional attacks; and penetrating tankers could persistently operate well within contested airspace by reducing their vulnerability to detection and targeting and defeating attacks that occur. Each of these typologies could encompass different aircraft concepts. For example, low-cost unmanned tankers could operate in standoff, stand-in, or penetrating roles depending on their survivability, mission, and acceptable level of risk.

The US Air Force, Marine Corps, and Navy possess fleets of C-130 aircraft variants capable of refueling probe-equipped receivers, such as some fixed-wing naval aviation aircraft, tiltrotor aircraft, and helicopters, normally at relatively low altitudes. These tankers are commonly referred to as tactical tankers, as opposed

Figure I.2. Typology of Tanker Employment in Contested Airspace



Note: Tanker images are of the Boeing KC-46A, Boeing ERA-009H1 concept, and Boeing "stealthy BWB", respectively.

Source: Authors.

to strategic tankers such as the KC-135 and KC-46A. To limit the scope of this project, it focused on the strategic tanking mission-set, although it did consider lower offload demands that overlap with the tactical tanking mission-set. Future analyses could examine the evolving demands of the tactical tanker fleets.

To interact with some of the models and budgetary plans used in this project, please access them at the report webpage: https://www.hudson.org/national-security-defense/resilient-reach-redesigning-us-air-force-aerial-refueling-contested-logistics-timothy-walton-shane-dennin.



1. THE DEMAND FOR AERIAL REFUELING

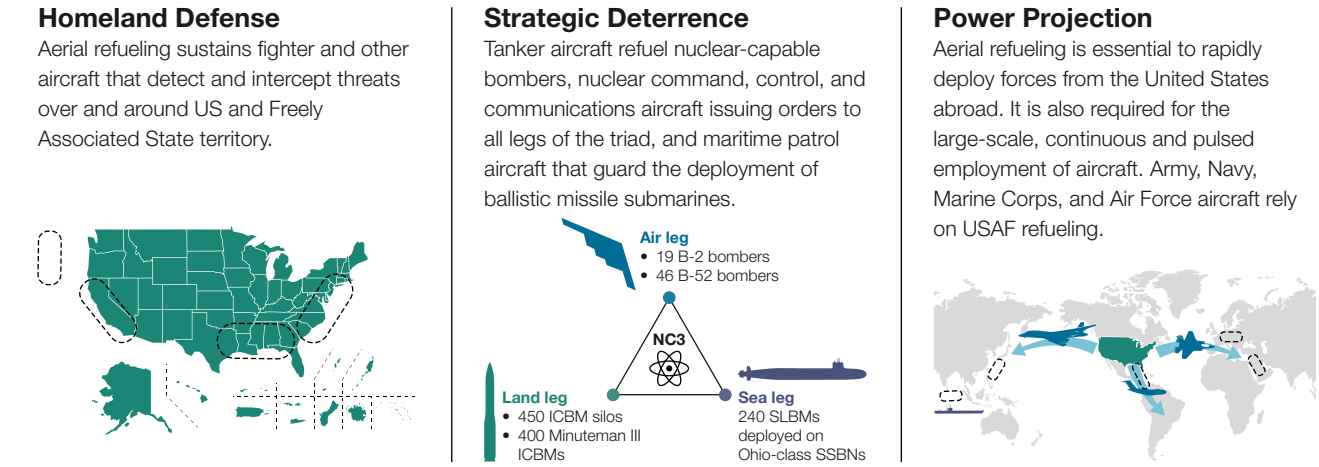
Aerial refueling is essential to US military strategy. As depicted in figure 1.1, it allows the US military to maintain strategic deterrence, defend the homeland, and project power for deterrence, warfighting, and other missions such as humanitarian assistance and disaster relief (HA/DR). It is one of the US military's most important advantages, and it allows US forces to operate globally.

Without appropriate aerial refueling, the US military could not effectively defend the large Western Hemisphere, much less promptly project forces over intercontinental distances and sustain operations across multiple theaters at scale. A lack of aerial refueling capacity would limit strategic options for US leaders, forcing the DoW to garrison a large fraction of its forces forward in a vulnerable posture, slowly attempt (and likely fail) to deploy forces in an expeditionary manner in a crisis or conflict, or mount an ineffective continental defense.

Understandably, demand for aerial refueling is high and growing. The majority of US military combat aircraft rely on it for a range of operations. Furthermore, for decades the Air Force has repeatedly employed every taskable tail to support concurrent combat operations, presidential visits, HA/DR, exercises, and regular deployments, and "in operational planning, aerial refueling is frequently one of the chief factors limiting the employment of supported forces."[25] The Air Force employed more than 200 tankers in Europe and the Middle East during Operation Epic Fury alone in 2026, and it required scores of additional tankers to maintain strategic deterrence, defend the homeland, and address other theater, diplomatic support, training, and depot maintenance demands.[26] In a large-scale conflict with the PRC or Russia, the far greater military challenges and distances of

Photo: A KC-46 Pegasus refuels an F-22 Raptor while an F-16 awaits a turn over the Mojave Desert on March 3, 2026. (DVIDS)

Figure 1.1. Aerial Refueling Enables US Military Strategy



Source: Authors.

the Indo-Pacific and Eurasian theaters would require even more tankers. In 2026 General Randall Reed, commander of the US Transportation Command (USTRANSCOM), testified that the airborne tanker force is the DoW's most stressed mobility fleet and called for increased air-refueling capacity.[27]

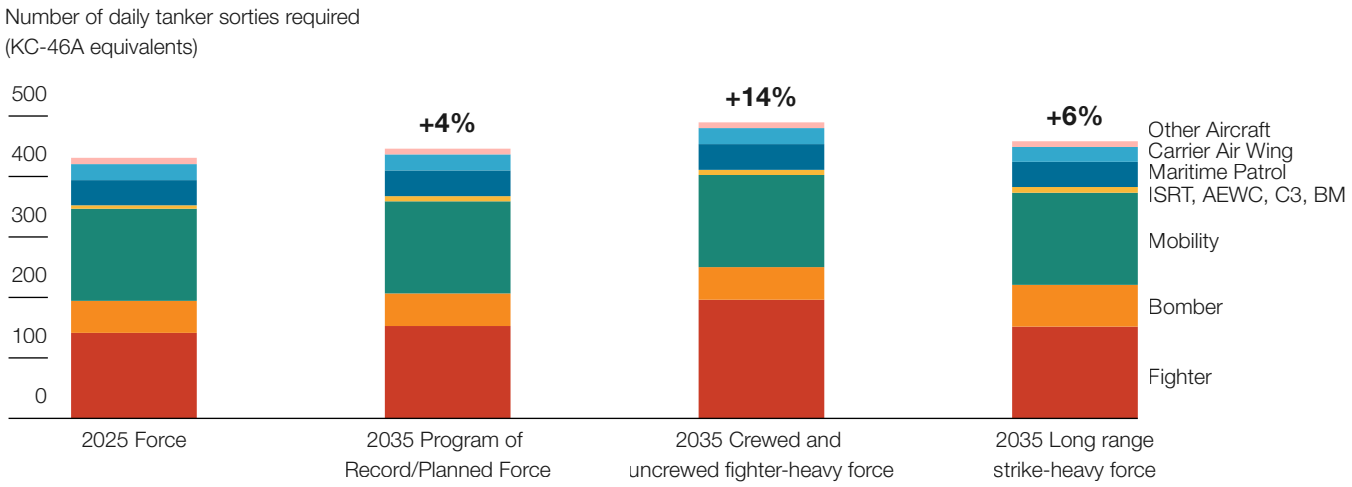
Given these high demands, the US Congress directed the Air Force to increase its aerial refueling fleet, mandating it maintain at least 466, 478, 490, and 502 tankers in fiscal years (FY) 2026, 2027, 2028, and 2029, respectively.[28] To do so, the Air Force will decrease the rate of KC-135 retirements as it inducts KC-46As into the force and increase the rate of KC-46A procurement from 15 to 18 aircraft per year from fiscal years 2028 to 2031.

As the US military services evolve their concepts, force designs, and force structures, aerial refueling demands will likely continue to be high. Current and emerging service and joint concepts emphasize greater distribution, dynamism, and tempo—all of which require the reach and endurance that aerial refueling support provides to enhance force lethality and survivability.[29]

Services are also introducing new platforms capable of aerial refueling, such as the Navy E-2D and P-8A.

As a countervailing trend, the US Air Force and Navy are prioritizing systems that could partially offset growing aerial refueling demands. Longer-range weapons could extend the reach of aircraft, reducing aerial refueling demands. The DoW FY 2027 budget proposal not only increases procurement of current preferred standoff munitions but also starts procurement of new low-cost, highly manufacturable weapons such as the Family of Affordable Mass Munitions and the Multi-mission Affordable Capacity Effector. In terms of aircraft, the Air Force is fielding longer-range B-21 bombers and F-47 fighters, new fuel tanks for its F-22 and F-35A fighters, and unmanned Collaborative Combat Aircraft Increment 1 designs that are not currently capable of refueling, and upgrading or considering upgrades to the engines of a variety of aircraft.[30] These initiatives that enhance the organic range of aircraft are laudable since they can increase the lethality and survivability of the force and reduce reliance on aerial refueling—especially in more-contested airspace.

Figure 1.2. Projected Aerial Refueling Demands in a Conflict with the PRC



Source: Authors.

However, in many cases, trends that continue or increase this reliance will offset such initiatives. For example, B-21 bombers will have a longer range and will rely less on aerial refueling than fighter aircraft. On the other hand, the Air Force plans to increase the size of its bomber fleet by at least a third within a decade, which will likely increase the aggregate demand for aerial refueling.[31] As another case, the Air Force is modernizing venerable B-52 bombers with more fuel-efficient engines, but equipping B-52Js with many large external missiles may cause a major increase in drag that counteracts those improvements.[32] And across bomber types, Air Force leaders have discussed new approaches to employ multi-bomber and other aircraft force packages in agile ways that would require greater endurance in the air, and in turn more aerial refueling.[33] Similar dynamics are at play within other parts of the Air Force and naval aviation. Furthermore, based on the testimony of the USTRANSCOM commander, the next USTRANSCOM Mobility Capabilities and Requirements Study may conclude that there is a requirement for even more than 502 tankers.[34]

Overall, regardless of changes in concepts, force designs, and force structures, future aerial refueling demands will likely be high. As shown in figure 1.2, we estimate that whether the Air Force and Navy adjust their force structures to emphasize shorter-range fighters or long-range strike assets, greater and more effective aerial refueling capacity is necessary.



2. PROBLEMS FACING THE AERIAL REFUELING FORCE

Despite the insatiable demand for aerial refueling, the Air Force's aerial refueling architecture has major problems. Most evident is the over-50-year-old average age of its tanker fleet. New KC-46A tankers are slowly replacing 1960s-era KC-135s at a rate of around 15 per year, but as of 2026, approximately 365 KC-135R/Ts are in active service compared with 113 KC-46As. KC-135s have undergone a service life extension that should enable a portion of the fleet to reach the 2040s, but the over-60-year-old age of the KC-135s increases the risk of fleetwide groundings or other catastrophic failures. It also contributes to steadily rising O&S costs (see figure 2.1).[35] Under current plans, the Air Force projects some KC-135 tankers to approach the century mark before retirement in the 2050s, and the Air Force may need to conduct another service life extension of the aircraft before their retirement.

Another major challenge is access and survivability of tankers in the air. Adversaries, in particular the PRC, have fielded numerous capabilities such as over-the-horizon radars and satellites to detect and potentially target high-signature tanker aircraft at long ranges in the air. Moreover, the PLA is fielding forces capable of engaging aircraft at long ranges, including supercruising low-signature fighters that it can refuel midair and that it has armed with long-range missiles, surface-to-air missiles with potential ranges of 2,000 km (1,079 nmi) (see figure 2.2), and naval formations.[36]

Photo: Sixteen KC-46A Pegasus and five KC-135 Stratotankers line up for an elephant walk during exercise Lethal Pride at McConnell Air Force Base in Kansas on March 27, 2023. (US Air Force)

Figure 2.1. Airmen from the 22nd Maintenance Squadron Complete an Isochronal Inspection of a KC-135 Stratotanker



Source: Adam Goodly, "220322-F-GC264-644," McConnell Air Force Base, March 23, 2022, https://www.mcconnell.af.mil/News/Photos/igphoto/2002962096.

Figure 2.2. Feitian-1 Hypersonic Vehicle, the Potential Basis for a PLA Very Long-Range Surface-to-Air Missile



Source: Stephen Chen, "Chinese Scientists Plan Surface-to-Air Missile with 2,000 km Kill Range," *South China Morning Post*, March 28, 2024, https://www.scmp.com/news/china/science/article/3256914/chinese-scientists-plan-surface-air-missile-2000km-range.

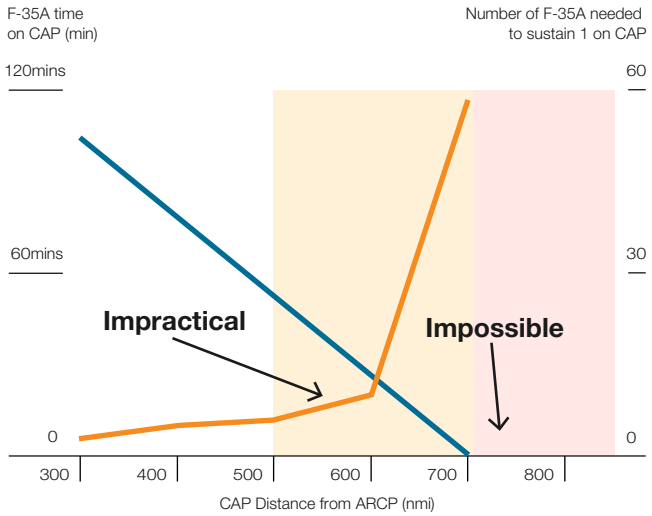
These and other threats could attrit many tankers in the air. They could also cause operational dislocations that impose virtual attrition on US forces by reducing their effectiveness. For example, as shown in figure 2.3, to avoid threats, aerial refueling tankers may need to stand back hundreds of nautical miles from the desired operating areas of fighter aircraft. In that case, performing the same mission could require many more and perhaps an impractically large number of fighter aircraft (thus reducing the total number of independent missions fighter aircraft could perform). At a certain stand-back distance, fighters cannot accomplish the mission. In this manner, threats to aerial refueling aircraft could challenge or defeat a mission even without destroying tanker or fighter aircraft.

In response, the US Air Force is pursuing longer-range weapons and increasing the organic range of combat aircraft. The threats have also driven Air Force interest in tanker designs that could enhance access and survivability in the air. In particular, the Air Force and US aircraft manufacturers have considered tankers with enhanced self-defense measures and reduced signatures that could penetrate or stand into contested airspace to refuel receiver aircraft.

Although threats to tankers in the air are significant, the greatest challenge to tanker operations is survivability on the ground. Deadly strike capabilities such as drones and missiles have proliferated across the world, increasingly have longer ranges, and can present large salvoes. Iran's potent attacks on Prince Sultan Air Base (shown in figure 2.4) that damaged tankers and destroyed other aircraft in 2026 are but a sliver of the much greater strike capacity the PRC could bring to bear.

In 2025 the PLA could already deliver thousands of PLA Air Force and PLA Rocket Force munitions per day against targets near its territory and around 400 munitions per day against targets in the Second Island Chain, the Middle East, and Central Asia. It could even strike Alaska and Western Europe with small numbers of weapons, as depicted in figure 2.5. By 2035, the threat will be far more severe; the PLA may be capable of

Figure 2.3. Long Tanker Stand-Back Is Untenable for Current Fighters



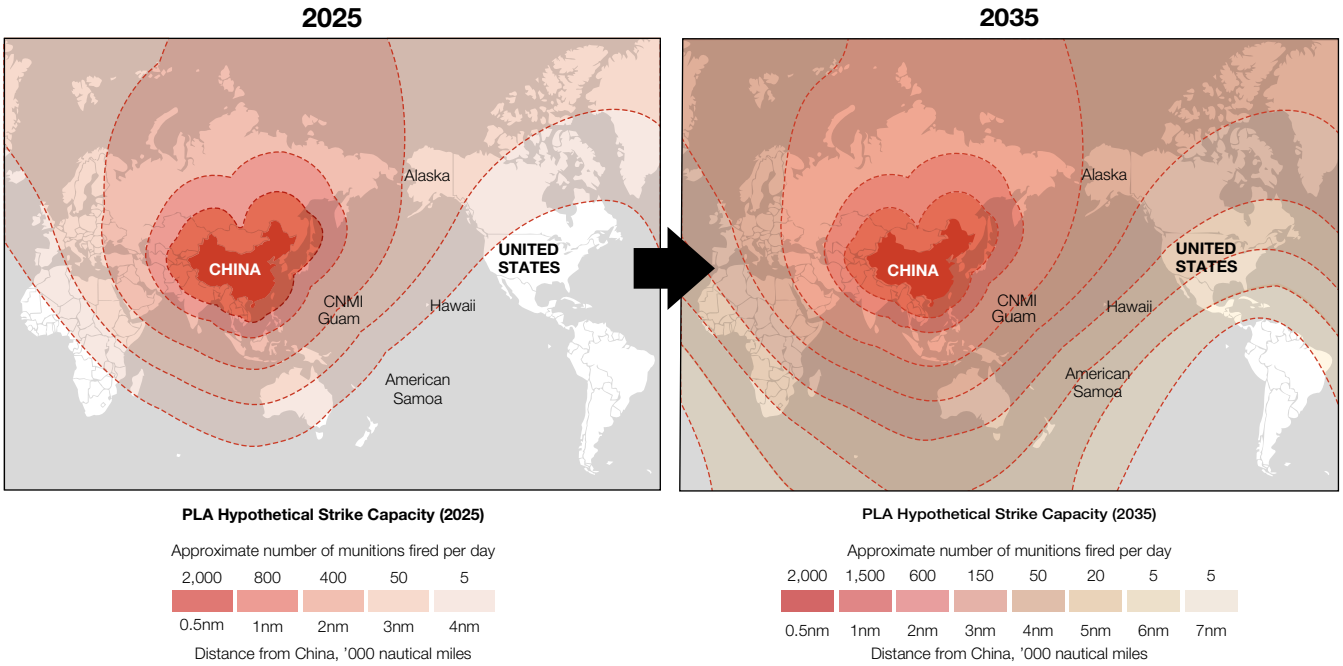
Source: Authors.

Figure 2.4. E-3G Airborne Early Warning and Control (AWACS) Aircraft Destroyed at Prince Sultan Air Base



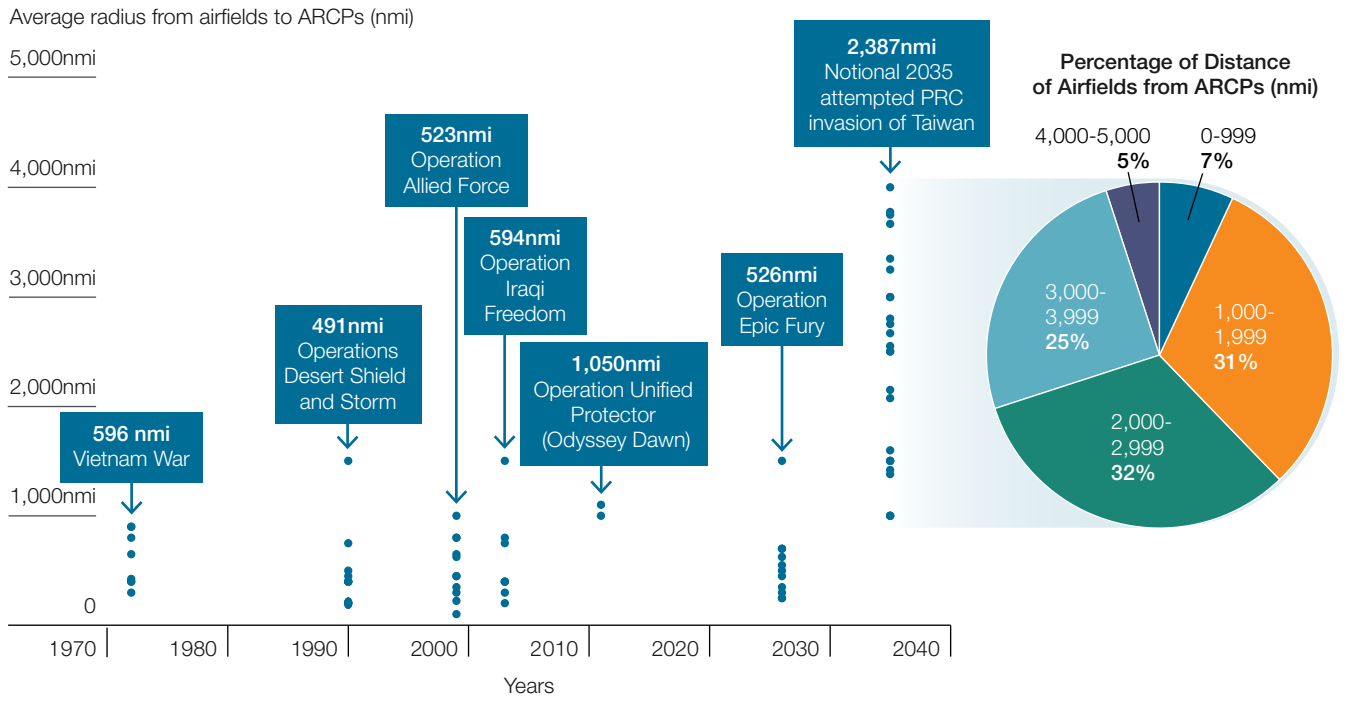
Source: OSINTtechnical (@Osinttechnical), "New image reportedly showing the USAF E-3 Sentry destroyed in an Iranian attack at Prince Sultan Airbase on Friday," X, March 28, 2026, https://x.com/Osinttechnical/status/2038063581070029135.

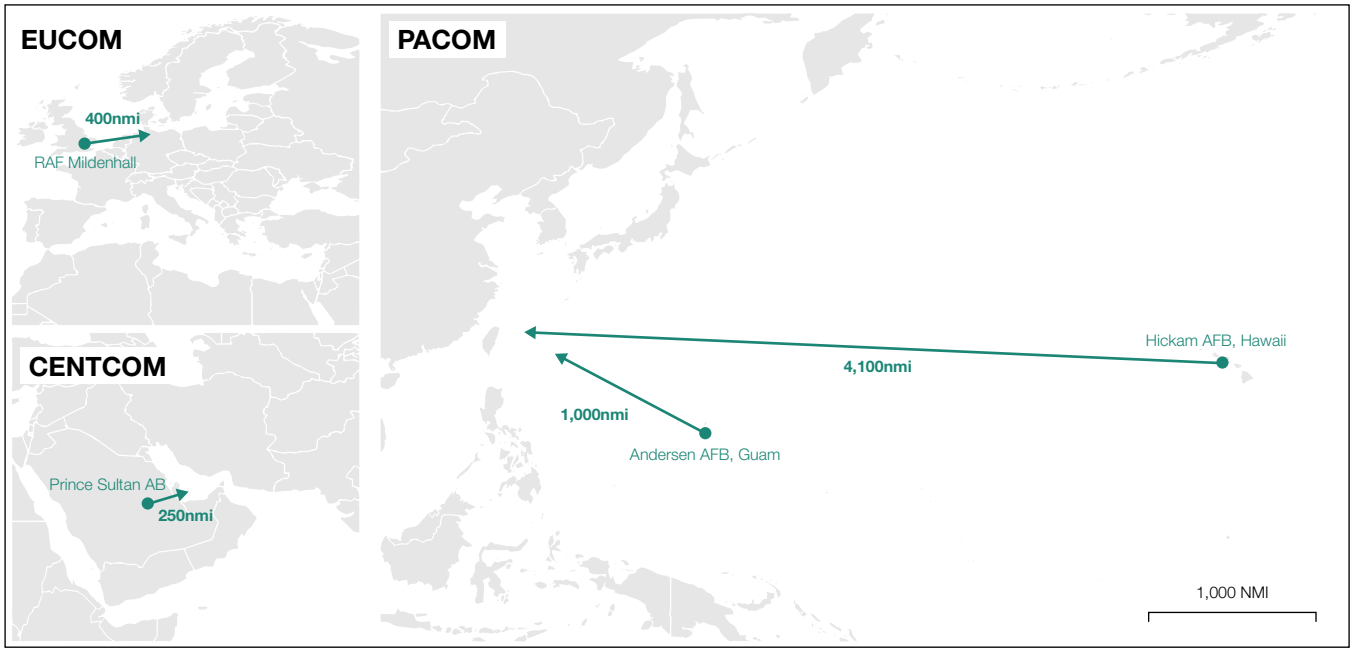
Figure 2.5. Estimated PLA Air Force and Rocket Force Conventional Strike Range and Capacity Absent Attrition



Source: Authors.

Figure 2.6. Estimated Weighted Average Distance from Tanker Bases to ARCPs





Source: Authors, with data drawn from various sources referenced in the endnote.[37]

delivering even more munitions and striking targets throughout Europe, Africa, and the Americas. This assessment does not account for additional attacks by the PLA Navy, PLA special forces in Operation Spiderweb–style attacks, or other threats. Although US and allied forces would conduct operations to neutralize and defend against enemy attacks, the projection illustrates that China will be capable of striking forces globally—especially near the PRC.

Long flight distances in the Indo-Pacific aggravate the threat that PLA strike capacity poses. As shown in figure 2.6, most US aerial refueling operations during major conflicts, including Operation Epic Fury, have originated from uncontested airfields relatively close to operating areas. As visible in the lower portion of figure 2.6, in a conflict with the PRC, most aerial refueling might take place from far more distant airfields—especially if planners eschewed operating large numbers of tankers from close-in airfields that would be more vulnerable to attack.

Flying from farther airfields, aerial refueling tankers burn more fuel while transiting to and from air refueling control points (ARCPs) or tracks and have less fuel to offload to receiver aircraft. US forces therefore require more tankers to perform the same mission and can execute fewer missions at the operational level. Moreover, to operate from distant airfields, current tankers such as the KC-135 and KC-46A require force extension in which one aerial refueling tanker refuels one or more other tankers that then deliver fuel to receiver aircraft. This valuable capability, equipped on the KC-46A, increases the effective range of tankers, and aircraft designers should incorporate it on future tankers. However, this approach consumes more tanker fuel and greatly reduces the effective number of tankers that can support aircraft.

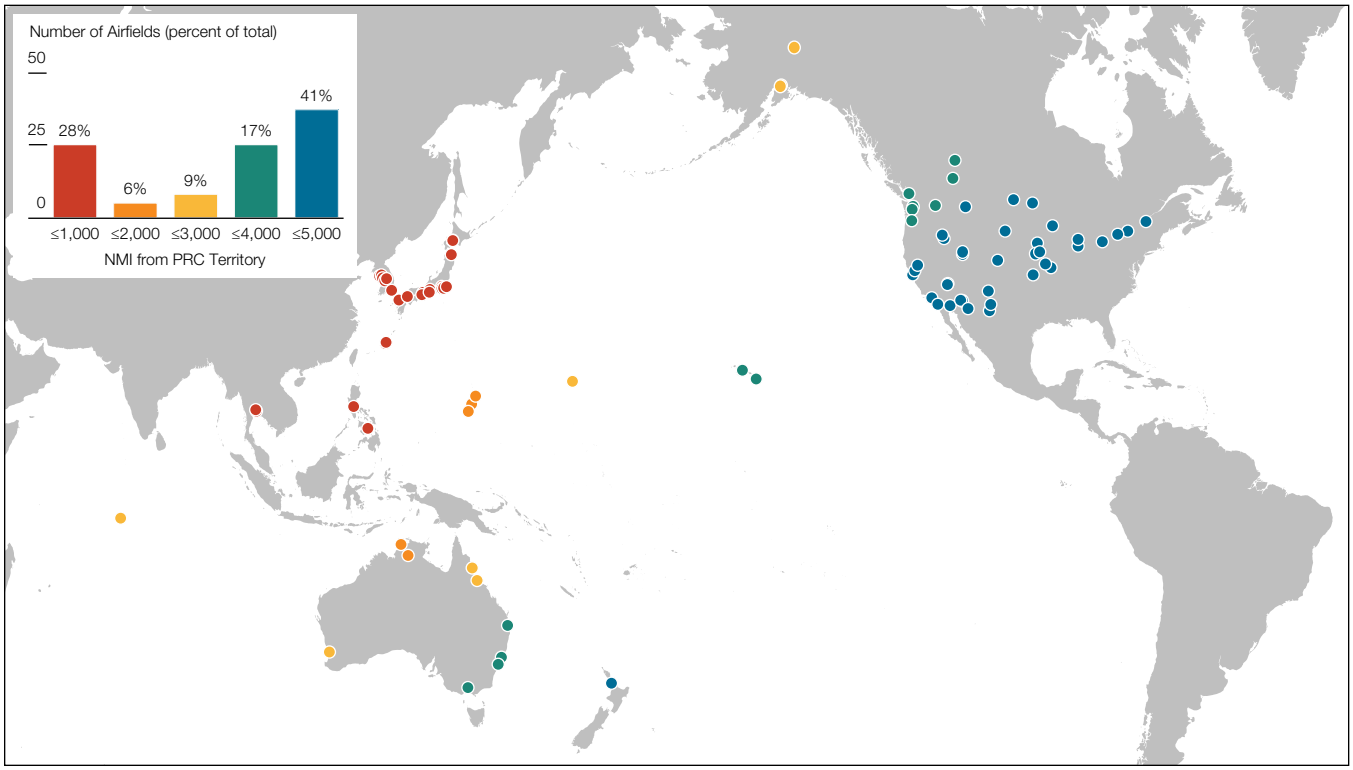
Consequently, a major gap in aerial refueling support may occur in a large-scale contested campaign against the PRC. In *Flipping the Script: Redesigning the US Air Force for Decisive Advantage*, Walton and Patt conducted theater-level simulations of a 2035 conflict with the PRC involving Taiwan. They found that the baseline force could have 40 percent of potential aerial refuelings unmet, as a significant portion of tanker aircraft flew from intermediate or distant airfields.[38] This gap hindered the ability of combat aircraft, in particular fighters, to perform missions and contributed to the baseline force's defeat in the scenario.

The relative dearth of airfields in the Indo-Pacific further compounds the access problem for US and allied forces and simplifies targeting for the PRC. Although there are nearly 1,500 airfields in the Indo-Pacific outside of adversary territory, few are suitable for tanker aircraft. For example, only around 90 of these Indo-Pacific airfields are on US and allied territory, are 5,000 nmi or less from PRC territory, and have sufficient fuel stores (and commensurate runway length, runway firmness, and parking area) to sustain the continuous operation of a squadron of KC-46A tankers for a week.[39] Fewer than half of those airfields have enough fuel stores to sustain tanker operations for two weeks. The distribution of airfields is also bimodal: many are close to or far from the PRC, but there are only 13 airfields more than 1,000 nmi and less than or equal to 3,000 nmi from PRC territory suitable for significant, sustained tanker operations (as shown in figure 2.7).

Other US aircraft, such as fighters or rotary-wing aircraft, could operate from a broader range of airfields, and US forces could gain access to more airfields on partner territory. Overall, though, this review suggests that fewer airfields are available for tanker operations than one might initially think and that more than two-thirds are either close to dense threats or distant. The implication is clear that tankers should be capable of effectively operating from distant airfields in addition to accessing forward ones.

Our analyses of the impact of potential PLA attacks against US and allied airfields in the Indo-Pacific underscore this conclusion. We find that by 2035, even if US and allied forces are

Figure 2.7. Approximately 90 US and Allied Territory Airfields in the Indo-Pacific Can Support Significant, Sustained Aerial Refueling Operations

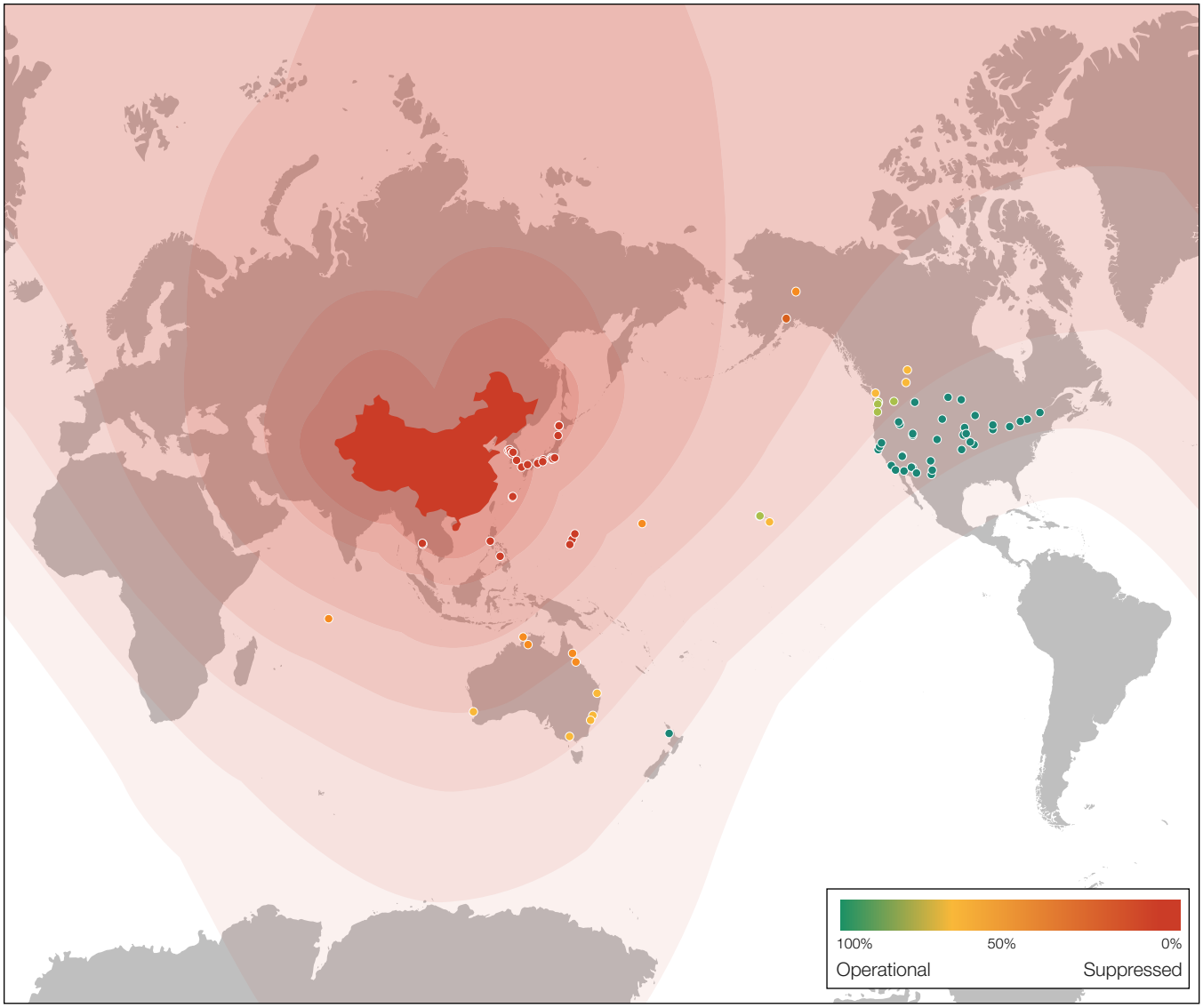


Source: Authors.

relatively effective at countering PLA attacks, the PLA may be capable of suppressing sustained tanker operations from forward airfields in the First and Second Island Chains as well as the Republic of Korea and Thailand. The PLA could also have an approximately 50 percent likelihood of suppressing each of the airfields in Diego Garcia, northern Australia, Wake Island, and Alaska. It may even be able to suppress some airfields in southern Australia, New Zealand, Hawaii, Canada, and the contiguous United States, as shown in figure 2.8.

In practice US and allied forces would likely adopt approaches that thin the level of threats and ensure continued tanker operations from some of these forward airfields. However, widespread suppression of the forward and many of the intermediate airfields that tankers normally rely on would hobble the US military's ability to conduct a range of critical operations, such as maintaining strategic deterrence, defending the homeland (in particular, US territories and the Freely Associated States, Alaska, and Hawaii), and projecting power with bombers and fighters. If properly equipped and garrisoned, many of these airfields may be capable of rapidly reconstituting from attacks and sustaining operations for fighter or other aircraft. But, sustaining large-scale tanker operations that require long runways and bulk fuel stores from these airfields under severe strikes will be far more difficult. In turn, sustaining joint force operations that rely on forward aerial refueling will be challenging.

Figure 2.8. Operational Status of Airfields for Sustained Tanker Operations after One-Week of Notional 2035 Conflict with PRC



Note: Figure depicts the mean result of 100,000 simulations of PLA attacks against airfields and accounts for estimated PLA threats, friendly defenses, and airfield characteristics.[40] It provides a conditional risk estimate of the operational status of airfields, rather than providing a prediction of the individual status of an airfield.

Source: Authors.

Facing this onslaught, the Air Force needs to transform. As *Flipping the Script* contends, the Air Force should prioritize the fielding of runway-independent Edge Forces that can fight forward without depending on airfields, long-range Pulsed Force bombers and weapons that can strike from a distance, and key enablers, particularly counter–command, control,

communications, computing, cyber, intelligence, surveillance, reconnaissance, and targeting (C5ISRT) and Resilient Airfields.[41] In terms of the Core Force's aerial refueling aircraft, the Air Force requires tankers that can effectively operate from distant airfields that are likely to face reduced levels of attack, as well as from forward ones, and can reach and survive at desired operating areas in the air. These survivability-on-the-ground and range problems are the chief challenges that should inform the development of the Air Force's aerial refueling fleet.

Potential conflict with the PRC is the principal driver of the need for longer-range aerial refueling capabilities. However, the demand is also present in other scenarios, including operations in the Arctic—which is thousands of nautical miles from large airfields with significant fuel stores in the contiguous United States or southern Canada—and other theaters. And, as mentioned, the short- and long-range strike capabilities that damaged tankers in Operation Epic Fury are proliferating among state and nonstate actors, posing threats to tankers wherever they operate.

As another example, in the lead-up to Operation Midnight Hammer against Iran in 2025, the US Air Force staged tanker aircraft in Europe and the Middle East given the medium range of KC-135 and KC-46A tankers. This tanker trail signaled that a large-scale strike against Iran would likely come from that direction. Although US forces reportedly achieved tactical surprise against Iran, a future adversary could exploit the tanker trail to counter an attack, including by attacking the tankers at their forward airfields. If US forces desired a higher level of operational security and reduced reliance on host nation access, they would require a longer-range aerial refueling capability.

Overall, the Air Force's traditional strength of aerial refueling is increasingly a liability. Decades of uncontested aerial refueling operations are ending, and the Air Force's current and programmed force structure depends on vulnerable airfields and bulk fuel stores along with medium-range tankers that are susceptible to attack on the ground and in the air. These weaknesses undercut the joint force's ability to conduct operations, and in expansive, highly contested theaters such as the Indo-Pacific, they risk causing the United States to lose a war.



3. SURFACE ARCHITECTURE AND MISSION SYSTEMS IMPROVEMENTS

The United States' aerial refueling architecture clearly needs to improve. Its old fleet of tankers is increasingly inappropriate for sustained operations against the PRC and faces limitations in other, less stressing scenarios. Some of the highest-value improvements to the Air Force's aerial refueling architecture, though, are not in new aircraft but in improved surface architecture and mission systems.

Strengthening the Surface Architecture

The aerial refueling surface architecture is "the network of airfields, maintenance facilities, and bulk fuel storage and distribution facilities and systems necessary to enable tanker operations."[42] "Enhancing the capacity and resilience of its surface architecture should be a top priority for the US Air Force—even if it comes at the cost of tanker procurement—because it will yield a greater increase in the number of tankers available and a greater amount of fuel delivered."[43] To strengthen US aerial refueling surface architecture, the DoW should pursue three primary initiatives: access more airfields, improve bulk fuel storage and distribution, and improve airfield defenses.

First, "DoD should improve the architecture's resilience by evolving today's brittle posture to a more distributed one that leverages clusters of mutually supporting military and civil airfields on US, allied, and partner territory."[44] "A mix of airfields at different distances is important to provide flexibility and mitigate threats, as airfields within and across clusters can mutually support each other and dynamically shift available offload capacity.

Photo: A fleet of US Air Force C-5M Super Galaxy, C-17 Globemaster III, and KC-46A Pegasus aircraft sit on the flight line at Travis Air Force Base in California on July 24, 2025. (U.S Air Force)

Additionally, assured access to forward and intermediate airfields is essential to generating relevant levels of tanker offload capacity. For example, it takes more than five times as many KC-46As operating 3,000 nmi away from their ARCPs to match the capacity that can be delivered by KC-46As operating a third as far away, at 1,000 nmi."[45]

The United States should "work to deepen international cooperation in terms of ground and overflight access for aerial refueling and other operations. Access to more locations, such as civil airports, would greatly increase tanker capacity in theater and complicate adversary targeting."[46] This includes allies and partners in the Indo-Pacific as well as in other regions. For example, North Atlantic Treaty Organization (NATO) allies are essential for the United States not only to maintain its ability to defend shared allied interests in the Euro-Atlantic but also to deploy and employ through Europe to Africa, the Middle East, or the Indo-Pacific. The United States should continue to nurture relationships with NATO allies, such as Portugal and Spain, that are vital to US aerial refueling operations and mend relationships in the wake of Operation Epic Fury.

A second class of necessary changes involves bulk fuel storage and distribution. "Current major gaps in fuel storage and maritime fuel distribution make large-scale, sustained, distributed aviation operations in the Pacific impractical. Many airfields lack enough fuel for sustained operations; their fuel storage tanks are predominantly above ground and vulnerable to attack; and they have limited over-the-shore fuel transfer systems, such as fuel piers, single-point moorings, or the Offshore and Inland Petroleum Distribution Systems. Coupled with munitions gaps, this is likely the most egregious weakness limiting the potential of US aircraft" and is a particular weakness for tanker operations that require large quantities of fuel.[47] Moreover, fuel is concentrated at large military and commercial airfields, which simplifies adversary planning by allowing them to focus on a small set of high-value targets (such as the 90 or fewer airfields shown in figure 2.7).

In response, the Air Force and broader joint force should improve its bulk fuel storage posture in a few ways. First, it should construct hardened fuel stores to replace aging tanks or install new ones, prioritizing airfields where "US forces are likely to have assured political access and face moderate threat levels."[48] Hardened fuel stores with underground or capped cut-and-cover tanks are three or more times as expensive as vulnerable aboveground storage, but they provide a much higher level of protection. Equally important, they force enemies to employ a larger number of unitary penetrator-armed warheads against individual hardened fuel tanks vice a smaller number of submunition-armed warheads that can destroy numerous aboveground storage tanks. This increase in required strike capacity imposes an opportunity cost on enemy attacks. It also increases the likelihood that active defenses, such as ground-based air and missile defenses, can successfully intercept enough attacking munitions while tolerating some leakers and ensure an appropriate capacity of fuel stores survives the attack. If aboveground storage tanks are constructed, whenever possible the DoW should disperse them to make it impractical for a submunition-armed missile to destroy multiple tanks at once.

Over the past few decades, to reduce costs, Defense Logistics Agency (DLA) Energy and the military services have largely shifted to constructing vulnerable aboveground storage tanks suited for uncontested operations. A prominent example is the recently completed aboveground storage tanks at Defense Fuel Support Point (DFSP) Darwin in Australia. It holds 1.9 million barrels of fuel (bbl) costing at least $272 million, enough to fill a squadron of tankers for seven months, in concentrated aboveground storage tanks. An adversary could destroy it with as few as two submunition-armed missiles, as depicted in figure 3.1.[49] Given that airfields and their fuel stores can now come under precision attack, the DoW should shift to constructing hardened fuel stores that drive up adversary salvo sizes and improve survivability. In light of the higher cost of hardened fuel stores and other fuel infrastructure, the Pentagon should either spend more on this critical need or accept a reduction in fuel

Figure 3.1. As Few as Two Missiles Could Destroy DFSP Darwin

Effects of submunition-armed missiles with a 450-foot radius of effect



Source: Authors, annotating Google Earth image.

storage capacity in exchange for better defended stores that have a much higher likelihood of surviving enemy attacks.

Conversely, the DoW should avoid building vulnerable aboveground storage tanks. For example, in the FY 2027 budget proposal for Wake Island (which suffered severe Imperial Japanese attack in World War II and could face an even more significant attack by advanced PRC capabilities in the future), DLA Energy has proposed concentrating 450,000 bbl of fuel in just three aboveground jet-fuel bulk tanks and one aboveground operating tank. Instead, it should construct hardened fuel storage and distribution infrastructure of the same capacity with additional funds. If additional funds are not possible, then it should construct a smaller-capacity yet far more resilient project. We estimate that for the same cost, DLA Energy could construct six 25,000-bbl capped cut-and-cover bulk tanks and three 10,000-bbl capped cut-and-cover operating tanks.

A second class of "necessary changes to the aerial refueling architecture consists of bulk fuel distribution. Although secure fuel storage is vital, the likely scale of large operations against major adversaries such as China or Russia means that it is unlikely the fuel stocks at airfields or DFSPs will suffice for protracted operations, and the high cost of hardened fuel stores means that it would be challenging to build enough fuel stores for very-long-duration operations. Additionally, fuel may not be sited at desired locations for distributed operations. Consequently, DoD should field capabilities needed to transfer fuel in bulk."[50]

These capabilities range from (1) an appropriate number of hydrants and fuel trucks at airfields for refueling tanker aircraft to (2) fixed and expeditionary over-the-shore fuel transfer systems that allow fuel from maritime tankers to reach constructed storage tanks and expeditionary bladders to (3) maritime tankers themselves. Some of these capabilities—especially in terms of airfield fuel distribution and intermodal links to airfields—are within the Department of the Air Force's portfolio. Others, such as maritime tankers, are outside of it. The Air Force should "vociferously articulate the need for [DLA Energy] to rapidly field necessary maritime fuel distribution capacity" through measures such as increasing domestic preference cargo, partnering with allies, and increasing working capital fund rates.[51]

And third, tanker airfields require improved passive and active defenses. As discussed in *Flipping the Script*, the Air Force can pursue a range of passive defense measures to improve the resilience of its airfields, including personnel and equipment bunkers, reconstitution equipment and units, redundant capabilities, the aforementioned fuel infrastructure hardening and other improvements, and hardened aircraft shelters and munitions magazines.[52] Although large hardened aircraft shelters suitable for tankers (see figure 3.2) can be expensive (ranging from $30–$150 million depending on scope and location), they can shield aircraft from observation and inclement weather, force adversaries to employ more numerous unitary weapons (rather than a small number of submunition-armed weapons),

Figure 3.2. Large Hardened Aircraft Shelters Can Protect Tankers and Other Aircraft, Such as the B-52



Source: Shane A. Cuomo, "Growing Mission," US Air Force, January 17, 2006, https://www.af.mil/News/Photos/igphoto/2000569825.

and protect tankers that cannot get airborne upon warning of an incoming attack. Tanker decoys could also shape adversary targeting. Lastly, active counter-C5ISRT and air and missile defenses are necessary to defeat threats. As the Iranian attacks on Prince Sultan Air Base show, dispersion alone is not enough to avoid attack in an era of persistent surveillance and precision targeting.

Evolving Mission Systems

Mission systems are the hardware and software that allow aircraft to perform their operational roles, as distinct from an aircraft's airframe and propulsion systems. Prioritizing the improvement of mission systems would achieve three objectives: address glaring gaps in tanker survivability, adopt an adaptive approach to aerial refueling operations, and mature systems that unlock capabilities for the next generation of tanker aircraft.

Most US Air Force tankers lack terrestrial tactical data links or high-bandwidth satellite communications. Accordingly, they lack an adequate ability to communicate in a secure manner or maintain situational awareness of friendly or other forces. As stated by former US Air Mobility Command Commander General Mike Minihan, mobility crews, including tanker crews, face a dilemma in which "they have to choose between being seen by everyone, including the enemy, or being seen by no one, including the joint force and civil aviation."[53] This lack of situational awareness may have contributed to a deadly midair collision between two KC-135s on March 12, 2026.[54]

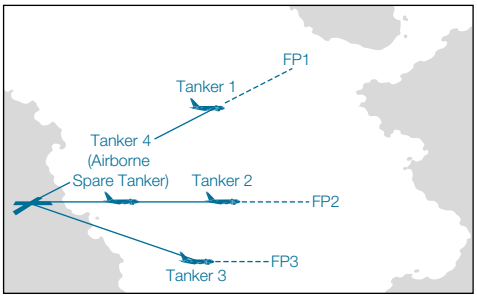
Fielding new tanker communications capabilities could allow crews to better respond to emergent friendly demands and avoid threats. Coupling these capabilities with onboard and offboard command and control and decision support tools could also enable more dynamic aerial refueling operations that enhance friendly optionality and frustrate enemy targeting.

New tools could also enable heterarchical command, control, and communications (C3) architectures that ingest higher-echelon data and guidance when available yet equip forward units with decision aids and information to gain and maintain the initiative. Bid-auction algorithms, which rideshare and other digital services use, or other methods could facilitate dynamic approaches to aerial refueling that provide more resilience and responsiveness.[55] For example, rather than servicing preplanned force packages at static ARCPs and tracks—a brittle approach vulnerable to enemy interdiction or other friction—tanker planners could push tankers forward and iteratively assign tanker-receiver pairings and operating areas in-flight. If enemies interdicted communications with higher echelons, software onboard each tanker would allow tankers and receiver aircraft operating forward at the edge near threats to organize using line-of-sight datalinks. This fluid approach could dynamically adapt to enemy threats or other factors, such as weather, while ensuring that tankers could reliably support demands. As the Air Force pursues greater distribution, tempo, and dynamism in its operations, these types of tools will be essential, and in 2026 the Air Force has started to resource improved tanker communications and decision support tools.[56]

Figure 3.3. Dynamic Aerial Refueling Planning

Pre-planned tasking

Each tanker is tasked with a specific track and force package before takeoff.



Pre-planned: At takeoff

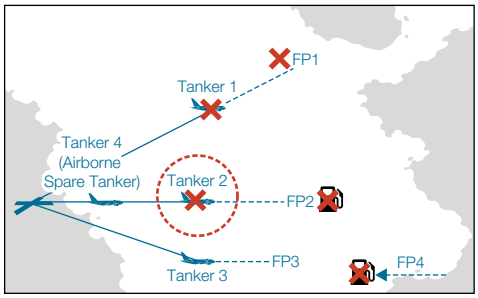
Fixed before takeoff

Tanker 1 ➔ ARCP 1 ➔ FP 1

Tanker 2 ➔ ARCP 2 ➔ FP 2

Tanker 3 ➔ ARCP 3 ➔ FP 3

Tanker 4 ➔ Airborne Spare Tanker



Pre-planned: At rendezvous

The plan has broken

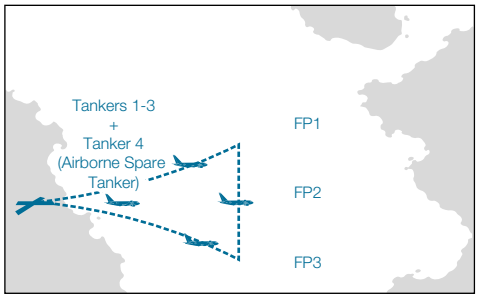
1. FP 1 was attrited by Red counter-air threat. Tanker 1 was unwarned or warned late, and is also attrited by the air threats.
2. A surface threat emerges in the ARCP 2 area, but Tanker 2 does not receive notice and is attrited. FP 2 suffers fuel exhaustion.
3. FP 3 is successfully refueled.
4. Unplanned FP 4 urgently needs fuel, but Tanker 4 (Airborne Spare Tanker) is mispositioned to refuel it. Asset 4 suffers fuel exhaustion.

Brittle approach

- 75% FPs are attrited by enemy or suffer fuel exhaustion.
- 50% tankers are attrited by enemy.

Dynamic employment

Tankers commit to a heading and maintain optionality.
Tankers then support receivers based on pre-planned and emergent demands.

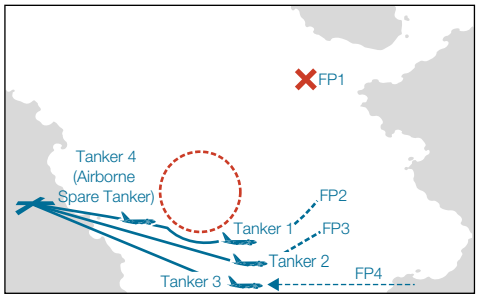


Pre-planned: At takeoff

Plan pushes capacity forward; organized at the edge

Tankers 1-3 ➔ FPs 1-3

Tanker 4 ➔ Airborne Spare Tanker



Dynamic: At rendezvous

Tankers address emergent demands

1. FP 1 was attrited by Red counter-air threat. Tanker 1 is warned in time, avoids threat area, and redirects.
2. Tanker 1 shifts to support FP 2 and routes around pop-up surface threat.
3. Tanker 2 shifts to refuel FP 3.
4. Tanker 3 shifts to refuel unplanned FP 4. Tanker 4 is directed early to refuel retrograding Tanker 1 and/or Tanker 3, which burned more fuel.

Resilient approach

- Only 25% FPs are attrited by enemy; none suffer fuel exhaustion.
- No tankers are attrited by enemy.

Source: Authors.

Given that adversary counter-air capabilities now extend to hundreds or possibly well over 1,000 nmi from operating areas, tankers will not be able to avoid all threats. Other US forces will fight to generate operational access for tankers and convert a denser array of threats into a more porous one that tankers can opportunistically fly into. Moreover, commanders may choose to operate tankers inside contested areas when needed at an elevated level of risk. On the whole, though, long-range, advanced counter-air threats can destroy and otherwise unfavorably shape tanker operations.

Tankers will need to operate inside contested airspace to refuel relevant receiver aircraft. However, current US Air Force tankers lack self-defense systems to reliably counter advanced counter-air threats. When the DoW assumed tankers operated in uncontested airspace, that limitation may have been acceptable. It is no longer.

Onboard sensors and kinetic and non-kinetic weapons and decoys, such as those proposed in the Air Force's Large Aircraft Survivability Systems (LASS) program, vary in terms of their difficulty to develop and field, but could enhance the ability of mobility aircraft to detect and defeat incoming threats.[57] In combination with broad-area counter-C5ISRT capabilities, long-duration surface- and air-launched decoys that mimic the signatures of tankers and other aircraft, and friendly counter-air capabilities, suites of self-defense systems could allow current and programmed tankers to operate in lightly or at the edge of moderately contested airspace at acceptable levels of risk.[58] Other onboard enhancements, such as emergency egress doors and parachutes, or even ejection seats on new tanker designs, could increase the survivability of tanker crews if their aircraft were lost.

Collectively, these measures could reduce tanker standoff distances, and in turn, the number of receiver aircraft necessary to support operations, as illustrated in figure 2.3. It could also force enemies to devote more targeting resources and weapons to consummate individual attacks, which would reduce their scale of effectiveness. Even if tanker aircraft cannot persist within contested or highly contested airspace at acceptable levels of risk, these new capabilities should grant tanker crews a reasonable chance of success against relevant long-range counter-air salvoes and enable tankers to shift from standoff operations to modest stand-in operations (see figure I.2), thus unlocking far more of the joint force's fighting potential.

The proposed C3 and self-defense improvements would come at a cost. In addition to the hefty financial price to develop some of these systems and outfit a portion of the tanker fleet with them (estimated at $10–$40 million per aircraft), they would impose operational penalties. On current KC-135 and KC-46A tankers, every pound of installed C3 or self-defense system comes at the cost of fuel that gross-weight- or runway-limited sorties could carry. Moreover, externally mounted systems would levy a drag penalty that would further reduce the effective offload capacity of tankers. The high signatures, fixed apertures, and power and cooling constraints of current tankers will also likely limit the potential effectiveness of self-defense system designs, which suggests future tanker designs should overcome at least some of these constraints.

No C3 or self-defense system, though, will comprehensively or persistently counter enemy threats. Instead of pursuing perfect mission systems, the Air Force should establish architectures that enable sustained software and hardware adaptation. Accordingly, it should prioritize the software ecosystem necessary to integrate different capabilities and program elements. Current and future tankers could leverage "open and dependable interfaces between platforms, their mission systems, and the ecosystem."[59] Such digital verification tools allow system software and hardware testing before integration with other system-of-systems elements and continuous contract vehicles for software and hardware. In this way, they could continuously and asynchronously improve system-of-systems elements.[60] This would allow software changes to occur in hours to days, and

mission system hardware changes to occur in weeks to a few years, unhindered by slower aircraft platform fielding timelines. It would also lower software and hardware system integration costs and timelines by facilitating integration with defined interfaces, vice requiring each program to chart its own integration path. Moreover, by integrating as part of or with the Air Force's broader Next Generation Air Dominance (NGAD) family-of-systems ecosystem, the mobility community could ensure its capabilities rapidly coevolve with NGAD improvements that address advanced threats. Overall, this approach would accelerate the iterative fielding of new mission system capabilities.

Equally important, the Air Force could establish digital architecture and contracts that allow for rapid adaptation in the face of adversary changes or emergent demands.[61] As the war in Ukraine and Operation Epic Fury in Iran demonstrated, combatants will rapidly evolve their digitally enabled capabilities, and mobility fleet system changes will need to outpace adversaries. Another benefit is that this approach would be more extensible across tanker types than platform-centric mission system development. KC-135s, KC-46As, and other current mobility aircraft could all benefit from C3 and self-defense system improvements. Moreover, maturing new C3, self-defense, and other mission systems on current tankers and demonstrator aircraft could allow future tanker types to more easily integrate these systems.

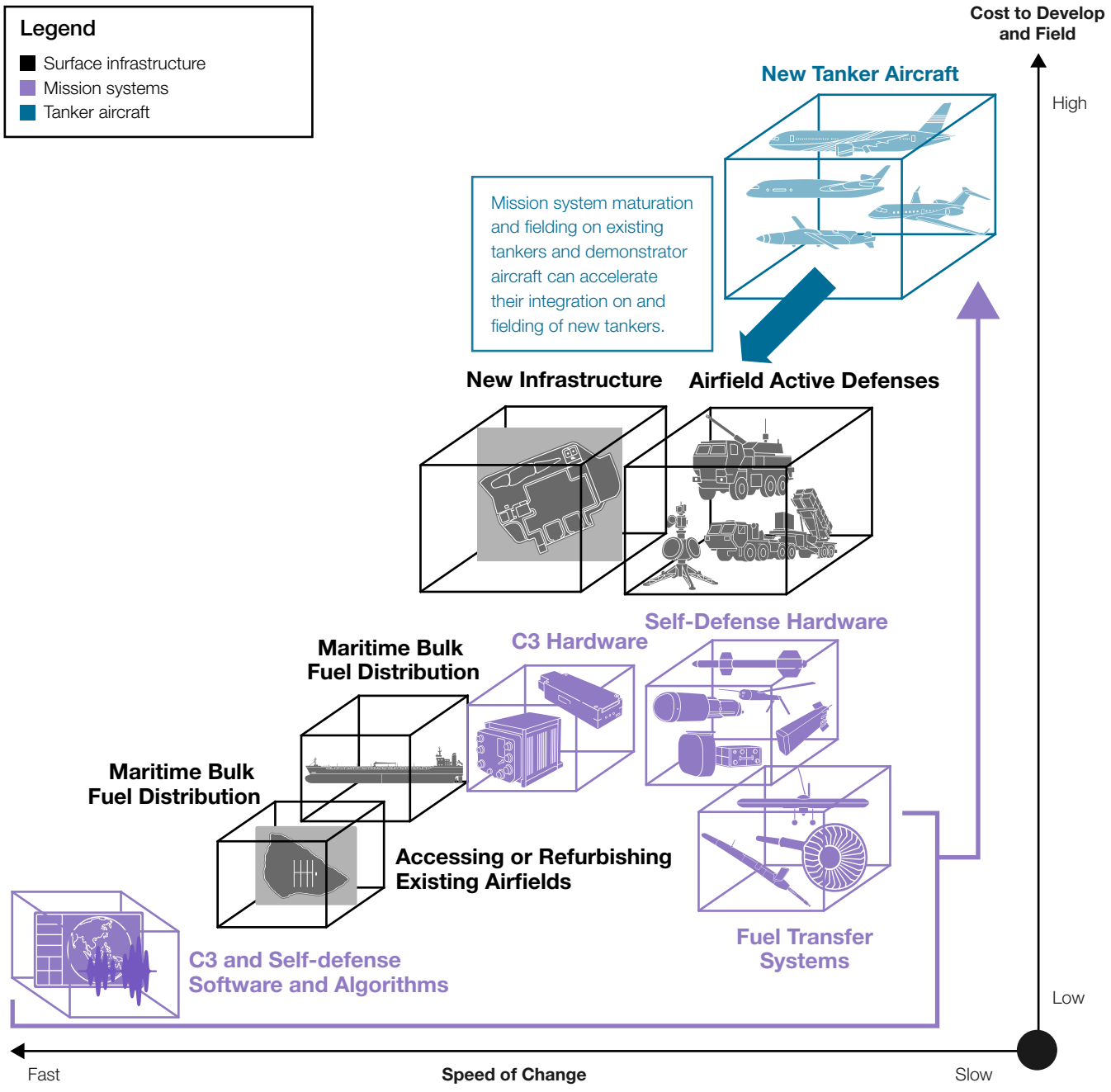
Other types of mission systems would also benefit from this architecture-first, software-defined approach, including fuel transfer systems and automation and autonomy. Current tanker booms are highly integrated with tanker aircraft and, as the delays of Boeing's Remote Vision System 2.0 show, can be slow to adapt in terms of hardware and software.[62] A new software ecosystem could allow progress in automatic and autonomous aerial refueling on one tanker type to be applicable to systems on other tankers. By leveraging the software ecosystem and harvesting remote vision data that the KC-46A captures, the Air Force could also facilitate the development of new fuel transfer systems for other tankers, including smaller and/or automated and autonomous booms.[63] Improved and new fuel transfer systems can generate fuel savings and improve the reliability of successful contacts.

Manufacturers could incorporate these new systems into future tanker designs. They could also more easily integrate them into modified commercial aircraft at a small scale in peacetime and at a large scale in a contingency, thus unlocking the potential of commercial aircraft fleets as latent war reserves.[64] One approach would develop an ability through the Combat Refueling and Operations Networked Universal System (CRONUS) program, Small Hybrid Aerial Refueling Kit (SHARK) program, and other initiatives to convert some commercial aircraft into manned or unmanned tankers in peacetime. It would also maintain enough ready kits (and access to crews on the ground and, if necessary, in the air) to tap into the much larger pool of commercial aircraft in a contingency.[65] Although these designs would not be optimized for aerial refueling, they could significantly offset tanker losses—especially by operating in less-contested areas.

More automation and autonomy are also necessary throughout the mobility fleet. Current US Air Force tankers require sizable flight crews, and on long sorties and over sustained campaigns, crewing becomes a major factor limiting the effective capacity of the tanker fleet. The service has, on average, more than two flight crews for every available tanker.[66] But due to other mission demands and training requirements, the number of crews available to operational squadrons may at times be lower. During operations in Europe and the Middle East, when long, repeated flights are coupled with rest and other requirements, the Air Force has only been able to maintain one or fewer sorties per aircraft per day from airfields 1,000–1,100 nmi from ARCPs.[67]

Faced with the prospect of needing to sustain sorties over much longer distances and under attack in the Indo-Pacific, Air Mobility Command has experimented with "Pilot + 1" operations. In these missions, rather than continuously flying with two pilots

Figure 3.4. Investments in Surface Infrastructure and Mission Systems Enhance the Effectiveness and Survivability of Current Tankers, Buy Down Risk, and Unlock Future Options



Source: Authors, inspired by figure 9 in Clark and Patt, *Building a Team for Next Generation Air Dominance*, 19.

and one or more other crew members active, only one pilot and one other crew member are active; the remaining crew members rest onboard or off the aircraft.[68] New automation and autonomy technologies could better support Pilot + 1 operations on current tankers, and on very long flights, they could enable largely autonomous flights in which crew are awake or on-duty for only the most demanding portions of the flight. Furthermore, as KC-135s are modernized, it may be possible to make some of them remotely operable. From the beginning, future tanker designs could adopt much higher degrees of autonomy and automation or be completely unmanned. Other automation capabilities, such as ones that optimize takeoffs on current and future tankers, could also improve the ability of tankers to operate with higher fuel loads from shorter or weather-affected runways.

By creating this software-defined architecture up front and separating the development and maturation of some mission systems from tanker aircraft, the Air Force could more rapidly field different sets of capabilities to current and programmed tankers, adopt an adaptive approach to aerial refueling operations, and (as seen in figure 3.4) mature systems that unlock capabilities for the next generation of tanker aircraft.



4. ASSESSING TANKER AIRCRAFT OPTIONS

Coupled with improvements to aerial refueling surface infrastructure, mission system improvements can enhance the ability of the current and programmed tanker fleet to effectively support operations in challenging scenarios, including a potential conflict with China. But they are not enough.

The KC-135 fleet needs replacement, and the characteristics of current medium-range KC-135 and KC-46A tankers make them vulnerable to enemy attack on the ramp and in the air. In addition, they are incapable of providing sufficient capacity in direct delivery or force extension to support large-scale, concomitant operations—especially as the military services embrace more distribution, dynamism, and tempo. Our simulations of potential conflict with the PRC conclude that, absent change, US and allied forces could suffer defeat, as their tanker-relevant airfields (and aircraft on them) could face heavy, repeated PLA attacks—even after distribution and dispersal—and 40 percent of potential receiver refuelings could be unmet.[69]

Accordingly, the Air Force should consider whether it should buy more KC-46A (such as the currently planned 75 or more KC-46A Tanker Production Extension aircraft) or pursue another design.

To explore this trade space, we examined the characteristics and operational performance of potential tanker aircraft in support of maintaining strategic deterrence, defending the homeland, and projecting power. Future tankers should enable the Air Force and broader joint force to rapidly deploy, pulse, and sustain forces at large scale under attack and enable greater joint force lethality, optionality, and resilience. Moreover, their attributes should address key problems facing the aerial refueling enterprise:

- *Fleet recapitalization.* The tankers should have reasonable research, development, test, and evaluation (RDTE) and pro-

Photo: A KC-46A Pegasus leads a two-ship formation with a KC-135 Stratotanker at McConnell Air Force Base in Kansas on September 29, 2026. (US Air Force)

curement costs. The goal is to allow for development and/or procurement amid competing budgetary priorities and procurement at rates similar to or exceeding that of the KC-46A in order to replace the old KC-135 fleet. Additionally, the tankers should have operational availability rates higher than current tankers to make the best use of fielded aircraft.

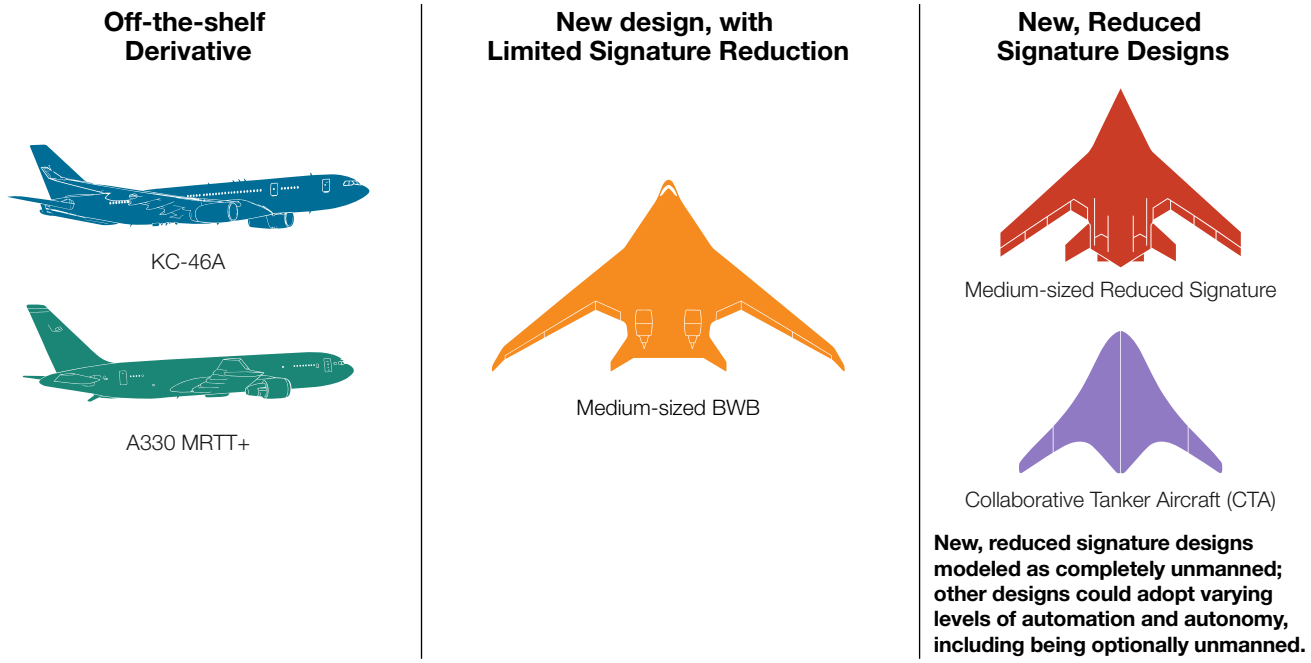
- *Contested airfields.* The tankers should have range and endurance to deliver appropriate offloads from numerous distant airfields and still be able to operate from forward airfields and moderate-length runways at full or reduced fuel loads. They should achieve higher operational availability rates and fast turn and scramble times to reduce susceptibility to attack on the ground.
- *Contested airspace.* The tankers should have size, weight, power, and cooling for C3, self-defense, and automation, as well as autonomy capabilities and potential signature management.

We also considered other, lesser aerial refueling fleet demands (dry cargo, aeromedical evacuation, and passenger transport) and the potential interaction between next-generation aerial refueling and next-generation airlift programs. Throughout our work, we sought to focus on the effectiveness of receiver aircraft and overall campaign effectiveness vice the aerial refueling inputs provided.

Reviewing Tanker Options

In terms of aircraft, this report assesses three general classes of designs (shown in figure 4.1): off-the-shelf derivative aircraft, new designs with limited signature reduction, and new reduced-signature designs. These designs are not intended to

Figure 4.1. Representative Tanker Concepts



Source: Authors, with the Medium BWB image based on the Boeing ERA-009H1 concept and the Medium Reduced Signature image based on a Boeing "stealthy BWB."[71]

Table 4.1. General Characteristics of Tanker Designs

	KC-46A	A330 MRTT+	MEDIUM BWB	MEDIUM REDUCED SIGNATURE	CTA
Empty weight (lb)	206,000	285,500	155,000	100,000	50,000
Fuel Capacity (lb)	212,000	245,000	300,000	125,000	75,000
Fuel fraction	51%	46%	66%	56%	60%
Required C-17 Parking Spots	0.84	1.37	0.57	0.40	0.32
Research, Development, Test, and Evaluation (RDTE) cost range (billions)	$1-3	$1-3	$6-8	$10-15	$4.5-7
Average Procurement Unit Cost (APUC) (millions)	$310	$315	$250	$295	$80
Total RDTE and Procurement Program Cost (billions)	$79.50	$80.75	$69.50	$86.22	$25.75
Program Average Unit Cost (PAUC) (millions)	$318	$323	$278	$345	$103

Source: Authors. See the endnote for information on the costing methodology.[72]

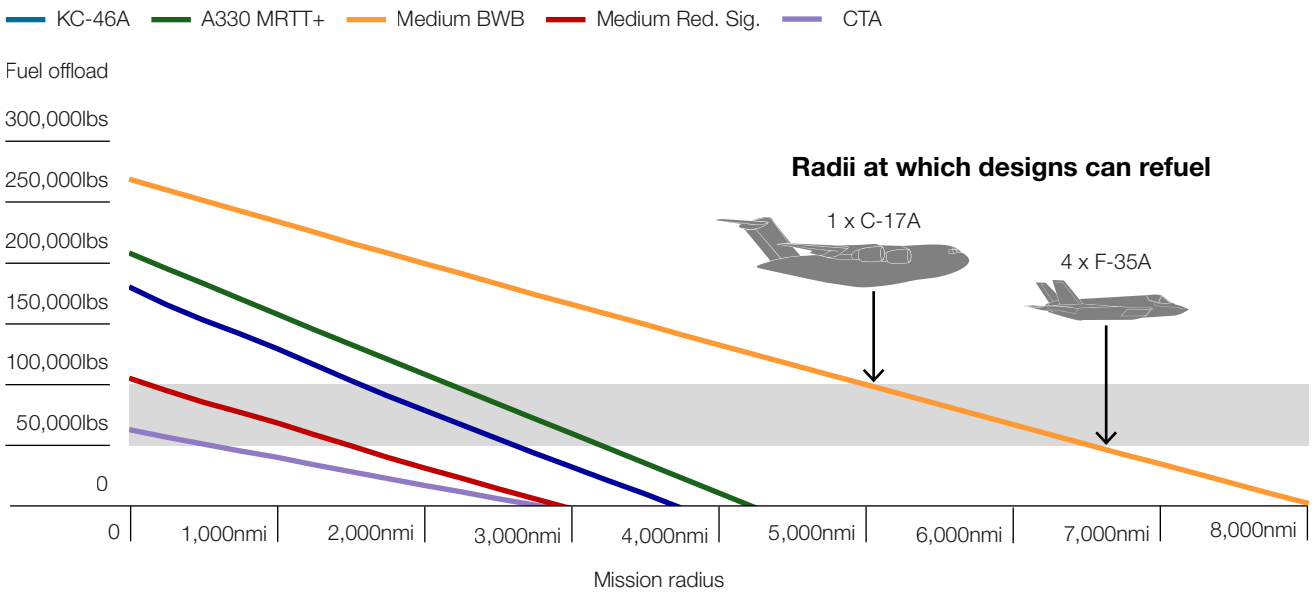
authoritatively define what tankers the Air Force could pursue but to serve as archetypes that illuminate major operational and programmatic dynamics that should inform the service's deliberations. Figure 4.1 depicts the principal tanker concepts evaluated in this report, table 4.1 lists the general characteristics of the designs, and figure 4.2 shows tanker fuel offload at radius when taking off with a full fuel load.[70]

KC-46A

The KC-46A is based on the commercial Boeing 767 aircraft and is the US Air Force's incumbent tanker. It is well-suited to deliver fuel at short-to-medium distances, with offload-at-radius performance similar to the KC-135 it is replacing, a greater and improved ability to transport dry cargo, aeromedical patients, and passengers, and modern mission systems. As depicted in the shaded area of figure 4.2, it can offload 100,000 lb of fuel to large aircraft such as the C-17A at a radius of approximately 1,500 nmi and 50,000 lb of fuel to a single four-ship of F-35A or one medium-sized aircraft at a radius of approximately 2,500 nmi. The KC-46A option we employed in our analysis had a more robust self-defense suite, which we judged enabled it to fly in our modeling 200 nmi closer to threats than the current KC-46A.[73]

In 2026 Chief of Staff of the Air Force General Ken Wilsbach testified to the US Senate Appropriations Subcommittee on Defense that, despite some deficiencies the KC-46A is a "phenomenal aircraft" that "has been doing a great job in Epic Fury

Figure 4.2. Estimated Tanker Fuel Offload at Radius When Taking Off with a 100 Percent Fuel Load



Note: Unless otherwise noted, our modeling assumes operation from dry and level runways that are at International Standard Atmosphere +15° Celsius (86° Fahrenheit) and 500 ft Pressure Altitude, and it uses the same mission profile, with offload taking one hour and one hour of reserve (45-minute Max Endurance Loiter at 10,000 ft and 15 minutes of Contingency Fuel). Assessments also dynamically account for airfield length, pavement firmness, ramp space, and fuel stores in assessing suitability for tanker aircraft and tankers' takeoff fuel load.

Source: Authors.

and all over the world."[74] The United States, Israel, and Japan are fielding KC-46As. Other nations such as Qatar may also procure them.[75]

Buying more KC-46As would allow the US Air Force to shift to an all–KC-46A force, which would provide fleetwide economies. At the same time, Boeing will end its commercial 767 freighter production in 2027, and coupled with a new contract to end its losses on the original KC-46A contract, this will contribute to an estimated 58 percent rise in KC-46A procurement cost.[76] Over time, it will also likely cause growth in KC-46A support costs as passenger and freighter 767s are gradually retired from commercial service, thus leading to a diminished supplier pool for parts.[77]

A330 MRTT+

The A330 Multi-Role Tanker Transport (MRTT)+ is based on the commercial A330neo aircraft and builds on the A330 MRTT, which more than 18 nations have selected. Compared to the KC-46A, it can deliver fuel considerably farther, transport a bit less cargo, and carry more aeromedical patients and passengers. As a larger aircraft, it takes up more space on the ramp and has slightly higher procurement, operations, and support costs than the KC-46A. There have been only 91 MRTT/MRTT+ orders to date, compared to approximately 185 firm KC-46A orders (and at least 105 additional US and foreign KC-46A orders); however, Airbus expects the commercial A330neo to remain in production well into the 2030s. The A330 MRTT+ option we employed in our analysis also had a robust self-defense

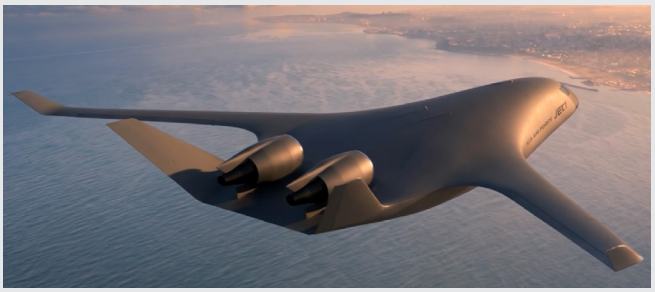
What Are Blended Wing Body (BWB) Aircraft?

BWB aircraft merge the fuselage and wings into a single lifting shape, reducing drag compared with most large aircraft that consist of a tube with wings attached.[79] Distinct from tube-and-wing and flying wing aircraft, the design was first developed in 1989 by Robert Liebeck at McDonnell Douglas. Since then, multiple firms have created BWB concepts and flown sub-scale prototypes, including established firms such as Airbus, Boeing (whose Medium BWB design is shown in figure 4.1), Bombardier, Lockheed Martin, and Northrop Grumman, and startups JetZero and Natilus.

In 2023 the US Air Force awarded JetZero, in partnership with Northrop Grumman, a contract to build and test a full-scale BWB demonstrator (shown in figure 4.3) that is scheduled to fly by the end of 2027. There is considerable commercial interest in passenger and freighter BWB aircraft since they could reduce fuel burn and significantly improve seat and cargo-mile economic performance. More aircraft production and new aircraft manufacturers could increase competition and help address burgeoning commercial demand for aircraft that has outstripped the supply provided by incumbents, chiefly Airbus, Boeing, and Embraer. Moreover, the maturation of aircraft design tools and composites manufacturing has improved the economic viability of scaled BWB production.

The PRC has also taken significant interest in BWBs. The Commercial Aircraft Corporation of China (COMAC), which the US DoW has recognized as a Chinese military company, is manufacturing tube-and-wing commercial aircraft.[80] It is also pursuing BWB concepts (as shown in figure 4.4) for potential commercial introduction in the 2040s. If the United States does not take the lead in applying BWB designs for commercial and defense applications, the PRC and other countries will likely do so.

Figure 4.3. Computer-Generated Image of JetZero's US Air Force BWB Demonstrator



Source: JetZero.

Figure 4.4. COMAC and Northwestern Polytechnical University–Developed Subscale BWB Commercial Airliner Flown in 2023



Source: Graham Warwick, "China Flies Subscale Blended Wing Body Airliner Concept," *Aviation Week*, February 3, 2023, https://aviationweek.com/air-transport/china-flies-subscale-blended-wing-body-airliner-concept.

system; in our modeling, this enabled it to fly 200 nmi closer to threats than the current KC-46A.[78]

Medium-sized BWB

In terms of developmental refueling-only designs, the Medium-sized Blended Wing Body (BWB) tanker (henceforth referred to as Medium BWB) is optimized to deliver high capacities of fuel at very long ranges. It can refuel multiple sets of receiver aircraft at long distances and support relevant force packages up to approximately 3,000 nmi farther than alternatives. To fly 300 nmi closer to threats than the current KC-46A in our modeling, it relied on a highly capable self-defense suite that benefits from a new design, adequate size, weight, power, and cooling accommodations, and potentially some passive aircraft signature management. However, like the KC-46A and A330 MRTT+, its externally mounted engines significantly affect its passive signature. To support long sorties, the crewed Medium BWB could have comfortable accommodations and a high degree of autonomy and automation that would allow a small or potentially no onboard crew to operate the aircraft. We estimated it would require $7 billion in RDTE to develop the aircraft and $250 million to procure each one on average. This is considerably less in procurement than the KC-46A or A330 MRTT+ options since, even though it incorporates an even more capable and expensive self-defense system than the current tanker options, it is a considerably lighter medium-sized aircraft that only delivers fuel rather than fuel, cargo, patients, and passengers.

Medium-sized Reduced-Signature

The Medium-sized Reduced Signature design (hereafter referred to as Medium Reduced Signature) has a significantly reduced passive signature, which challenges adversary surveillance and targeting in the air, further enhances the effectiveness of its robust self-defense suite, and allows it to fly up to 500 nmi closer to threats than the current KC-46A. Although it has the range to independently support receiver aircraft at short distances, it excels at shuttle tanking, in which as a child tanker it penetrates contested airspace, delivers about 75,000 lb of fuel to receiver aircraft at a 750 nmi radius (or higher offloads at shorter radii), and spends a protracted period shuttling back and forth from parent tanker KC-46As or KC-135s. The Medium Reduced Signature design could be unmanned or manned and was modeled in our analysis as unmanned, taking off in some of our analyses from contiguous United States airfields and staying airborne for 72 hours as it shuttled back and forth from parent tankers. This concept of employment greatly reduced its vulnerability on the ground, but it depended on the operations and survivability of parent KC-46As. Developing this advanced aircraft may cost around $12.5 billion in RDTE, but given its considerably smaller size and weight, it could surprisingly cost slightly less in procurement than the KC-46A option.

Although our study used one type of Medium Reduced Signature design to illustrate necessary tanker attributes, other Medium Reduced Signature design concepts are possible. Other reduced signature tanker designs could potentially cost less to develop and field—especially if procured in small numbers as a tailored force to address a small number of challenging missions.

CTA

Lastly, the unmanned Collaborative Tanker Aircraft (CTA) also has a reduced signature, albeit not as low as the Medium Reduced Signature aircraft, and some airborne countermeasures, which allow it to fly 400 nmi closer to threats than the current KC-46A in our modeling. It is optimized for shuttle tanking on 72-hour sorties from contiguous United States airfields, delivering 50,000 lb of fuel from a 500 nmi radius, as it draws fuel from parent tankers. The CTA is the least expensive developmental option in terms of both RDTE and procurement.

Other Design Concepts

Other design concepts considered as part of this project included the KC-10, a KC-46B with 10 percent longer range than the KC-46A, a 777-8-based tanker, a large BWB that could carry dry cargo and passengers in addition to fuel, various small CTA, and proprietary tanker concepts. In general, these designs fell

within the performance range of the five baseline designs, and thus we did not include them in this report. For example, we initially thought a 777-8-based tanker could provide a prodigious quantity of fuel at long range to either independently support receiver aircraft or serve as a parent tanker. However, analysis demonstrated offload-at-radius performance generally between that of the A330 MRTT+ and Medium BWB at longer radii—especially when imposing runway length, temperature, and pressure altitude limits. Accordingly, we did not include it in this report's five representative designs. A similar dynamic emerged when examining the performance of the Air Force's now-retired, previous high-offload tanker, the KC-10.

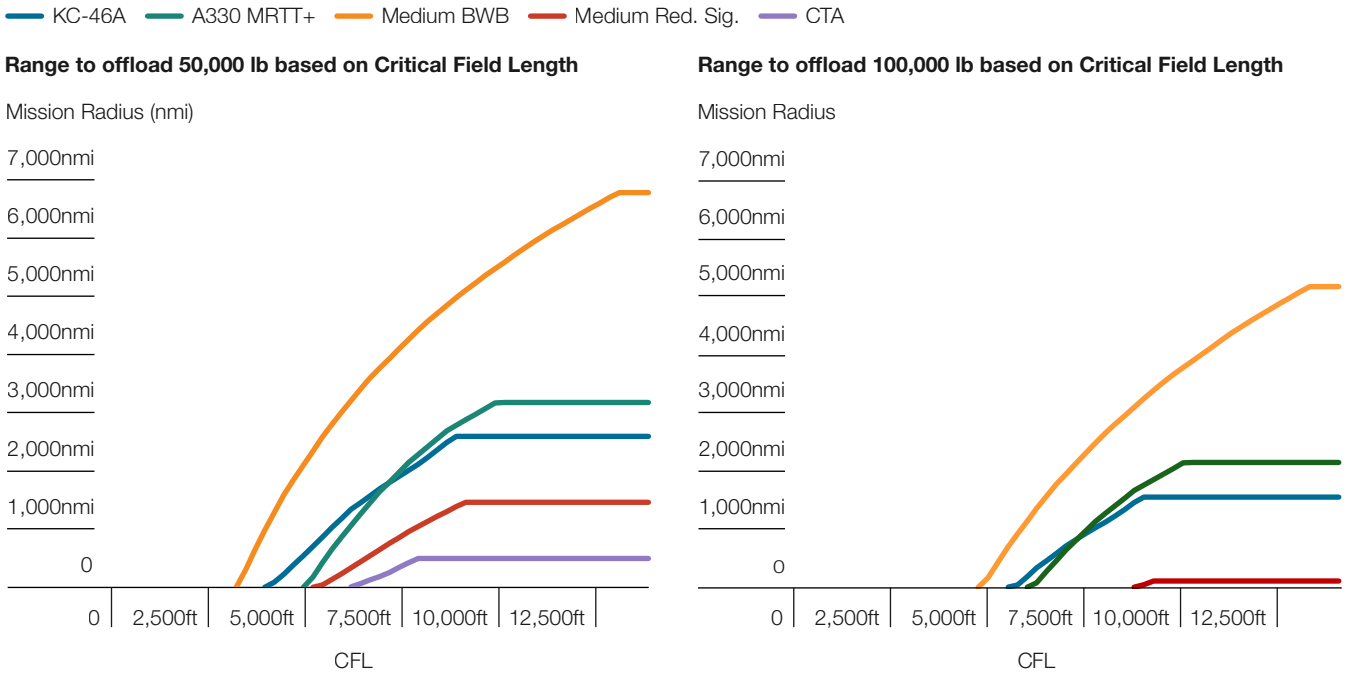
Performance Comparison

To examine the design space for future refueling tankers, we assessed their level of airfield access and performance attributes. In addition, we considered their ability to support relevant mission vignettes set in Pacific Command, Northern Command, European Command, and Central Command, to sustain theater-level operations under PRC attack, and to support force deployments.

The ability to access suitable airfields while supporting relevant missions is essential for runway-dependent tankers. To assess tanker options, we analyzed Indo-Pacific airfield accessibility, accounting for airfield runway length and width and aircraft Critical Field Length (CFL) at varying aircraft fuel loads. We also considered pavement firmness requirements at varying aircraft fuel loads, available ramp space and aircraft size, working ramp area required, and airfield fuel stores.

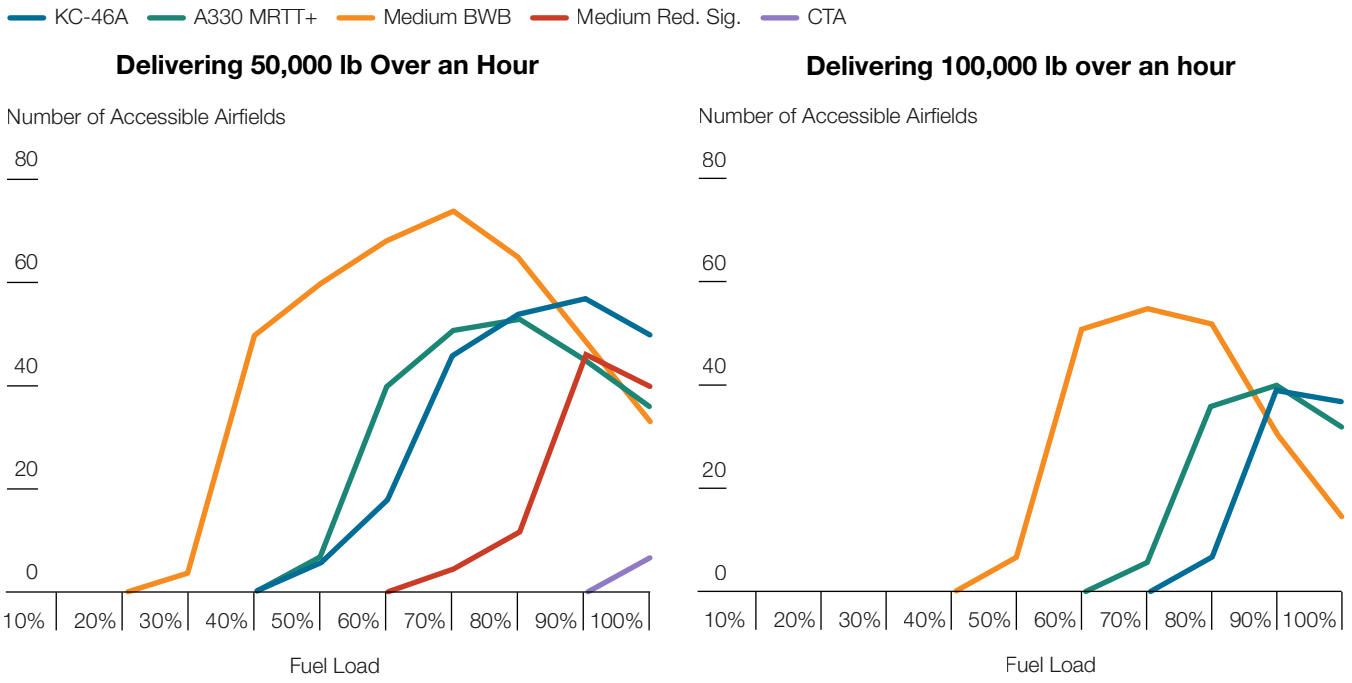
Figure 4.5 shows that when comparing the takeoff performance of the tanker options in support of relevant offload missions, across

Figure 4.5. Range to Offload Fuel Based on Critical Field Length



Source: Authors.

Figure 4.6. Number of Airfields from Which Tankers Can Support an ARCP in the Philippine Sea



Note: These charts estimate the number of airfields from which tankers can support an ARCP in the Philippine Sea. The measure of effectiveness is the highest total number of airfields from which tankers can operate, at any fuel load percentage. In both cases, the Medium BWB can operate from the highest number of airfields. For most designs, as fuel load percentage increases, the number of airfields that tankers can operate from increases and then decreases, since at the modeled environmental conditions, high fuel loads takeoff length and pavement firmness requirements increase, which limits the number of suitable airfields. This trend is most pronounced in the Medium BWB.

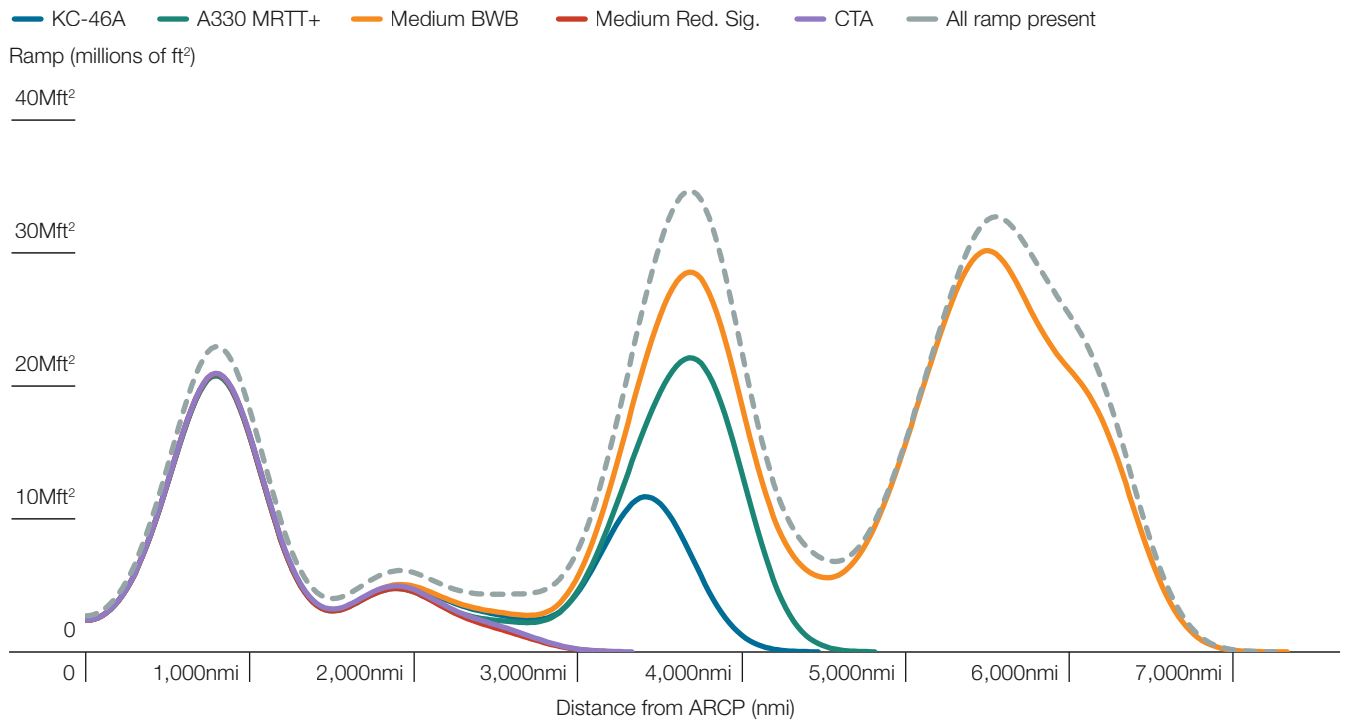
Source: Authors.

all runway lengths, the Medium BWB flies thousands of nautical miles farther than other designs when delivering relevant offloads of 50,000 or 100,000 lb. The difference is even more pronounced at higher offloads. This performance enables it to take off from long runways and fly very long distances as well as to take off with a reduced fuel load from short, 5,000 ft-or-less runways and still refuel receiver aircraft at a considerable distance.

One might think the relatively light Medium Reduced Signature and CTA designs could take off from short runways. However, when they carry considerable amounts of fuel to support receiver aircraft, the fuel-efficient in the air (but moderately powered on the ground) designs we examined must generally operate from moderate-to-long runways and can only do so at short radii. Thus, counterintuitively, the KC-46A, A330 MRTT+, and Medium BWB can all operate from shorter runways than the Medium Reduced Signature or CTA when carrying relevant fuel loads.

The ability to access many airfields at varying fuel loads and perform relevant missions allows the Medium BWB to also operate from the greatest number of airfields. Figure 4.6 examines the number of airfields tankers can operate from when independently delivering fuel to an ARCP 500 nmi southeast of Taipei in the Philippine Sea. In support of this mission, the Medium BWB can operate from 1.3–1.4 times as many airfields as the KC-46A and A330 MRTT+, since it can fly not only from

Figure 4.7. Useful Ramp Area and Distance from ARCP



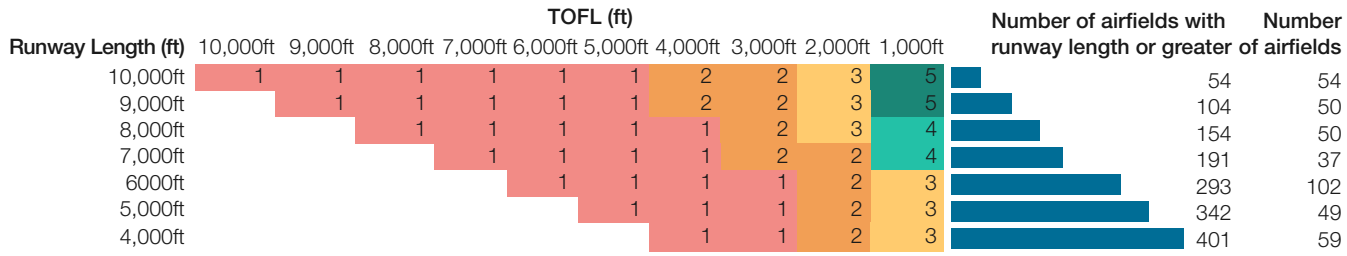
Note: The total amount of "All ramp present" accounts for the dispersion of aircraft in response to airfield threats.[81]

Source: Authors.

airfields in the Western Pacific but also from intermediate and distant ones. The Medium Reduced Signature design can access 46 airfields throughout the First and Second Island Chains when delivering 50,000 lb offloads, which is only 11 airfields fewer than the KC-46A. When directly delivering 50,000 lb of fuel to receiver aircraft, the CTA can surprisingly operate from only seven airfields, underscoring that the aircraft is optimized to work as a shuttle tanker with parent tankers. Subsequent figures 4.10–4.14 show the performance of these shuttle tanking designs when supported by force-extending parent KC-46As.

Another way to visualize airfield accessibility is by assessing how much ramp space across Indo-Pacific airfields each tanker design can usefully employ. An airfield's ramp space may not be useful to a tanker if it is too far from an ARCP or if the pavement grade, runway length, or fuel storage is insufficient for the aircraft. Moreover, as illustrated in figure 2.7, there is a dearth of airfields at intermediate distances, meaning most airfields are either close-in and under threat or distant from the primary area of operations. In order to directly refuel an ARCP that is 500 nmi southeast of Taipei in the Philippine Sea, figure 4.7 shows how much ramp space at tanker-relevant airfields a tanker design can feasibly leverage in a conflict depending on its distance from the ARCP. Unless aided by parent tankers, Medium Reduced Signature and CTA designs must constrain their operations to forward airfields. In contrast, the KC-46A, A330 MRTT+, and Medium BWB can operate from a broader range of airfields in direct delivery, employing 29 percent, 40 percent, and 88 percent of potential ramp space, respectively.

Figure 4.8. Estimated Number of Runway Strikes to Render a Runway Inoperable Depending on Aircraft Takeoff Field Length (TOFL) and Runway Length



Source: Authors.

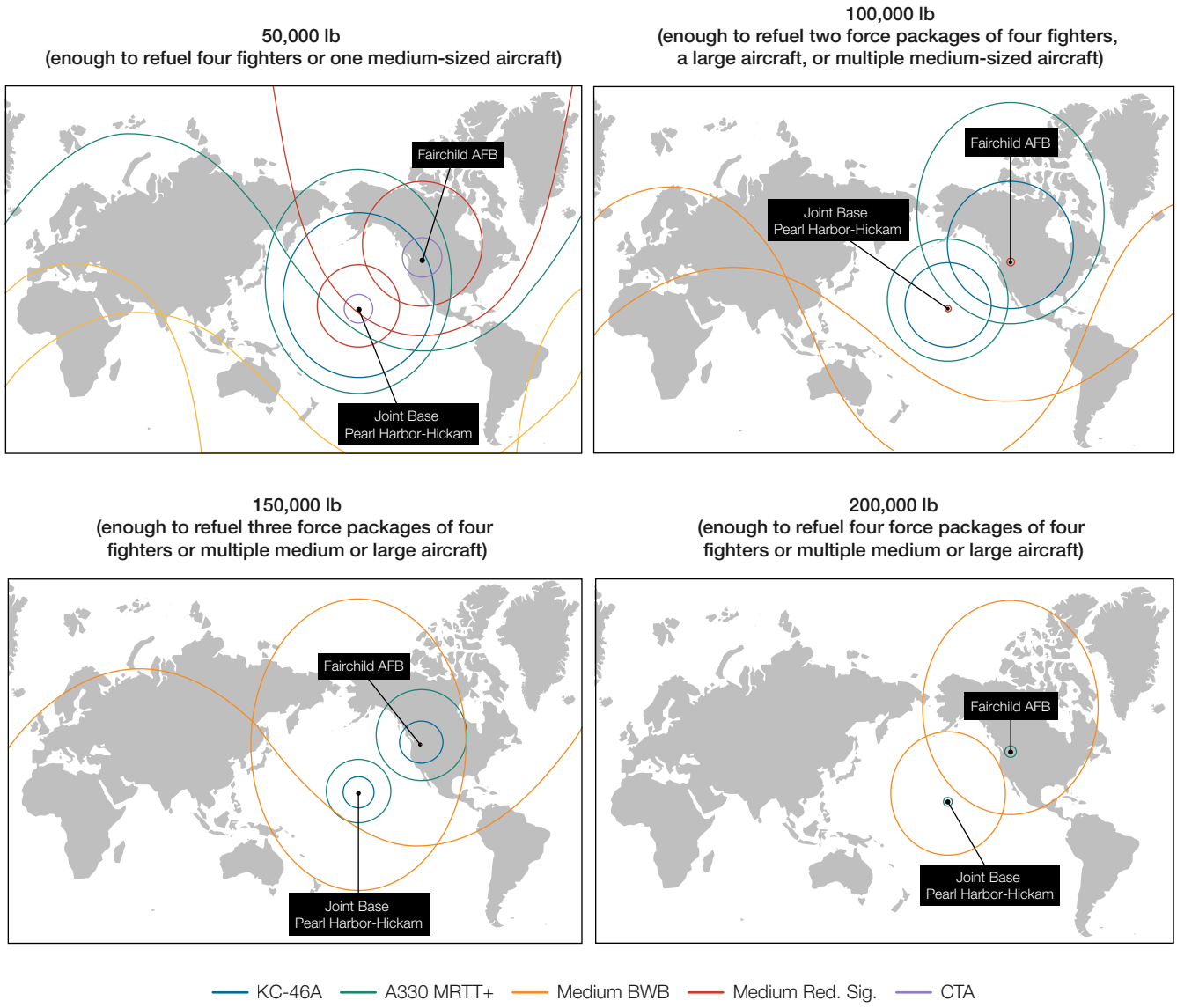
The Air Force should critically evaluate the ability to operate tankers from short runways, either to access more airfields to distribute aerial refueling operations or to operate from runways that have been damaged. First, most airfields that have fuel stores appropriate for tankers also have 8,000 ft or longer runways, while short runways tend to have little fuel stored. For example, all the airfields in our Indo-Pacific database with enough fuel to sustain a KC-46A squadron's operations for a week have runways of 8,000 ft or longer. Second, as depicted in figure 4.8 analyzing Indo-Pacific airfields on US and allied territory, a small number of well-aimed strikes can render runways inoperable for tankers, including short takeoff-optimized ones. And third, as figure 4.5 shows, when medium or large tankers reduce their fuel load, they can take off from relatively short runways and still support relevant missions.

Therefore, the Air Force should critically assess the relative value of the ability to take off from short runways at high fuel load fractions compared to other performance attributes.[82] It should also avoid fixed CFL requirements (e.g., "must be able to operate from 8,000 ft runways at full fuel loads") since such a requirement unduly affects the design trade space. Instead, the Air Force should embrace effects-based analyses that examine the ability of tankers to support relevant missions from different runway lengths at varying fuel loads and under different takeoff field length requirements and airfield conditions.

As shown in figure 4.2, the Medium BWB can deliver far more fuel farther than the other options. It can provide three or four 50,000 lb offloads (enough to each support a four-ship of fighters such as F-35A or one medium-sized aircraft) or multiple 75,000–100,000 lb offloads (each enough to support medium and large aircraft such as transport aircraft and bombers) at thousands of nautical miles. Compared to the significant but still incremental additional range and offload that the A330 MRTT+ brings relative to the KC-46A, the Medium BWB can provide more than twice as much offload and range, and it unlocks opportunities to employ US and allied forces more effectively.

Expressed in the Pacific, Medium BWBs could operate not only from airfields in the Western Pacific but also from ones in Hawaii and even the contiguous United States and deliver relevant offloads (as shown in figure 4.9). This extraordinary offload at range enables more dynamic and resilient operations since the Medium BWB could support receiver aircraft in different areas for longer and could access more airfields, including distant ones that would be more difficult to suppress. Moreover, by being able to deliver high, 150,000–200,000 lb offloads at range, the Medium

Figure 4.9. Radius of Tankers Offloading Fuel over an Hour



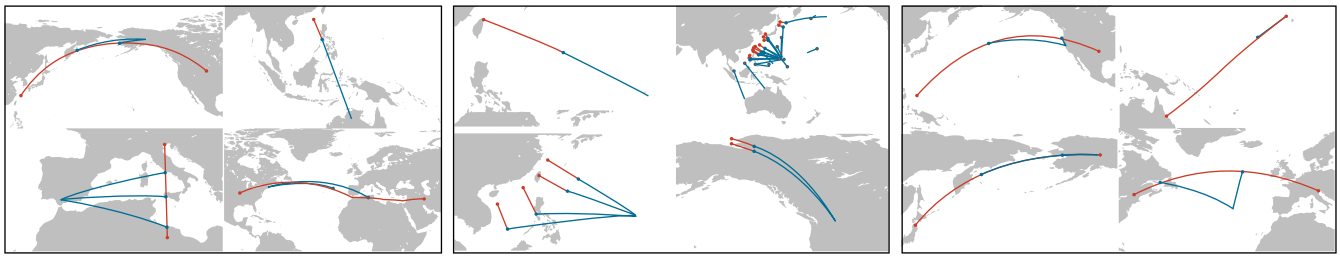
Source: Authors.

BWB could better support fuel-intensive bomber pulsed operations and tanker bridges for fighter or transport aircraft at scale from distant airfields, or surge to provide refueling over areas where tanker airfields or operations have been suppressed by enemy action. Lastly, greater offload at range could also translate into greater endurance and maneuverability, allowing supported force packages to opportunistically attack, defend, and feint for longer.[83] These advantages could enable operations throughout

Figure 4.10. Performance and Cost of Tanker Options in Mission Vignettes

DESIGN	TOTAL TANKERS REQUIRED		TANKER FUEL BURNED		TOTAL COST (PAUC)		TOTAL RAMP SPACE REQUIRED	
	RANK	RELATIVE TO KC-46A	RANK	RELATIVE TO KC-46A	RANK	RELATIVE TO KC-46A	RANK	RELATIVE TO KC-46A
KC-46A	3.2	100%	3.3	100%	3.7	100%	3.5	100%v
A330 MRTT+	2.5	87%	3.3	97%	3.1	89%	4.6	142%
Medium BWB	1.6	70%	1.6	57%	1.5	61%	1.7	54%
Medium Red. Sig.	3.9	154%	3.8	121%	4.8	165%	2.7	85%
CTA	4.9	213%	4.0	121%	2.9	94%	3.6	105%

OCA/Strike Vignettes **DCA CAP Vignettes** **Deployment Vignettes**



Source: Authors.

the Pacific. As the maps demonstrate, though, they could also better support operations over the Arctic and other regions.

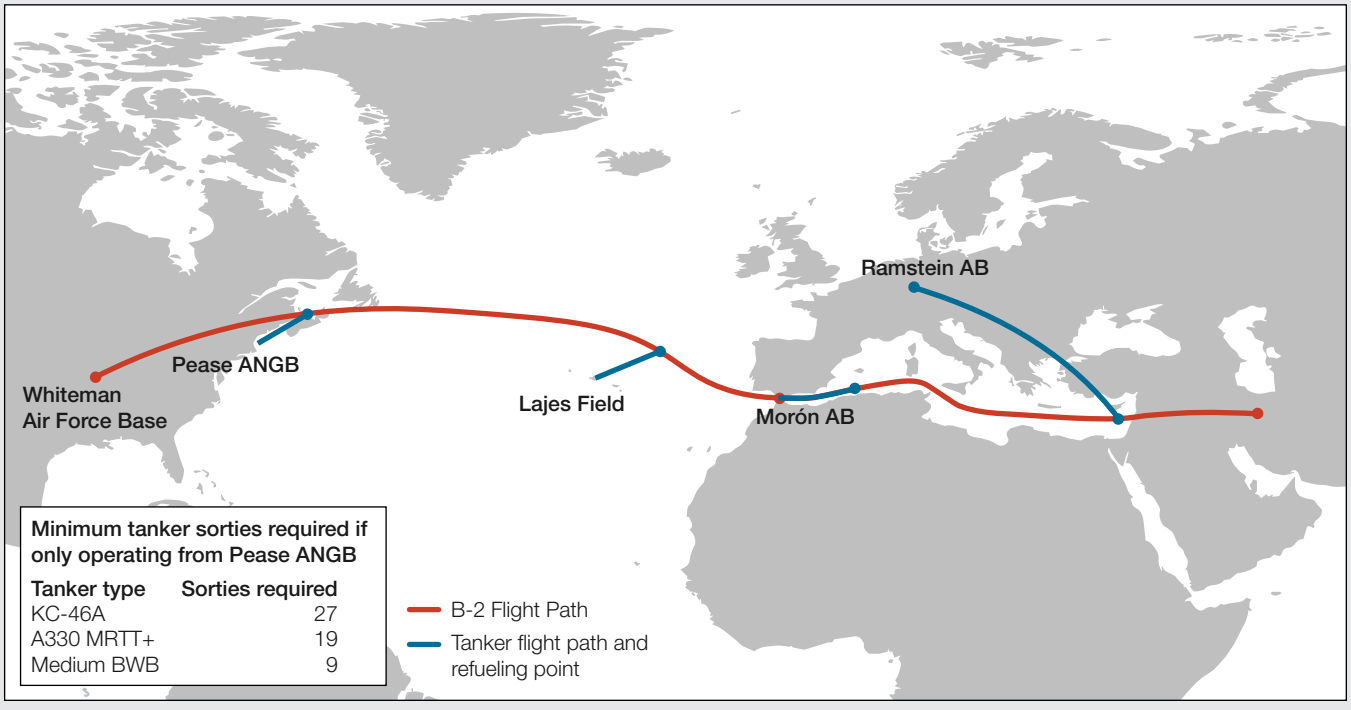
The Air Force would likely seek to employ a significant fraction of its tanker aircraft from intermediate and forward airfields. The location and number of tanker aircraft operated at these airfields would need to be metered by the efficacy of US attacks against and defenses from enemy forces, and in turn the level of attrition that could be tolerated on the ramp (and sustainability and operability of the airfields after attack). Nonetheless, tanker aircraft flying from intermediate-distance airfields (such as ones in Diego Garcia, northern Australia, and the Central Pacific) and forward airfields (such as ones in Thailand, the Republic of Korea, and the First and Second Island Chains) could support higher sortie rates and could deliver more fuel to receivers than aircraft flying from distant airfields (such as ones in southern Australia, New Zealand, Hawaii, Canada, and the contiguous United States), regardless of tanker type.

Midnight Hammer Redux

Another type of stressing vignette involves supporting long-range bomber pulses. Many of these operations require numerous tankers. Given the medium range of the KC-135 and KC-46A, they also require either the staging of tankers at airfields near the planned flight path of tankers or force extension operations. Tanker staging signals potential activities along a certain approach, and force extension involves more tankers to refuel those offloading fuel to receiver aircraft. As a recent case study, in the Operation Midnight Hammer strikes against Iran in 2025, "more than 125 US aircraft" were involved, including "dozens and dozens of air refueling tankers," and the seven B-2s that struck targets completed "multiple in-flight refuelings."[85] In advance of the operation, the US Air Force deployed tankers to airbases in Europe (potentially including Portugal, Spain, the United Kingdom, Germany, Italy, and Greece) and the Middle East, which could have signaled to adversaries that potential strikes would come along that route.[86]

As an alternative, if the US Air Force had wanted to execute the strike directly from the contiguous United States to reduce

Figure 4.11. Representation of Potential Aerial Refueling Routes in Support of Seven B-2s in Operation Midnight Hammer, and Minimum Tankers Required if Only Operating Tankers from Contiguous US Airfield



Source: Authors.

potential indications and warning of an attack, it would have required even more tankers. As seen in figure 4.11, when focusing on only support to the seven B-2s, current KC-46A and A330 MRTT+ options would have required a minimum of 27 and 19 tankers, respectively, while the Medium BWB would have required nine—one-third of the KC-46A amount.

The ability to operate from allied and partner territory is essential to the US ability to maintain strategic deterrence, defend the homeland, and project power in support of its own and allied interests. The United States should nurture its relationships with countries that have granted US forces access to their territory in defense of shared allied interests. Moreover, it is impractical for the United States to successfully execute large-scale operations solely from its contiguous territory, in particular for shorter-range aircraft such as fighters. However, an ability to promptly execute short-notice global strikes with tanker support can benefit the US and its allies and enhance deterrence. Long-range, high-offload tankers such as the Medium BWB could fulfill such missions.

However, the ability to operate from distant airfields would provide far greater force optionality, resilience, and an ability to credibly execute large-scale, short-notice operations from the contiguous United States, regardless of threats. It would also provide a hedge for US force planners in case US forward posture in regions diminished. For example, if US forward presence at some airfields in the eastern Middle East were to be reduced, as is being considered by the Pentagon, the addition of long-range, high-capacity tankers such as Medium BWB could provide more flexibility in how to employ the force from more distant airfields in the western Middle East or Europe.[84]

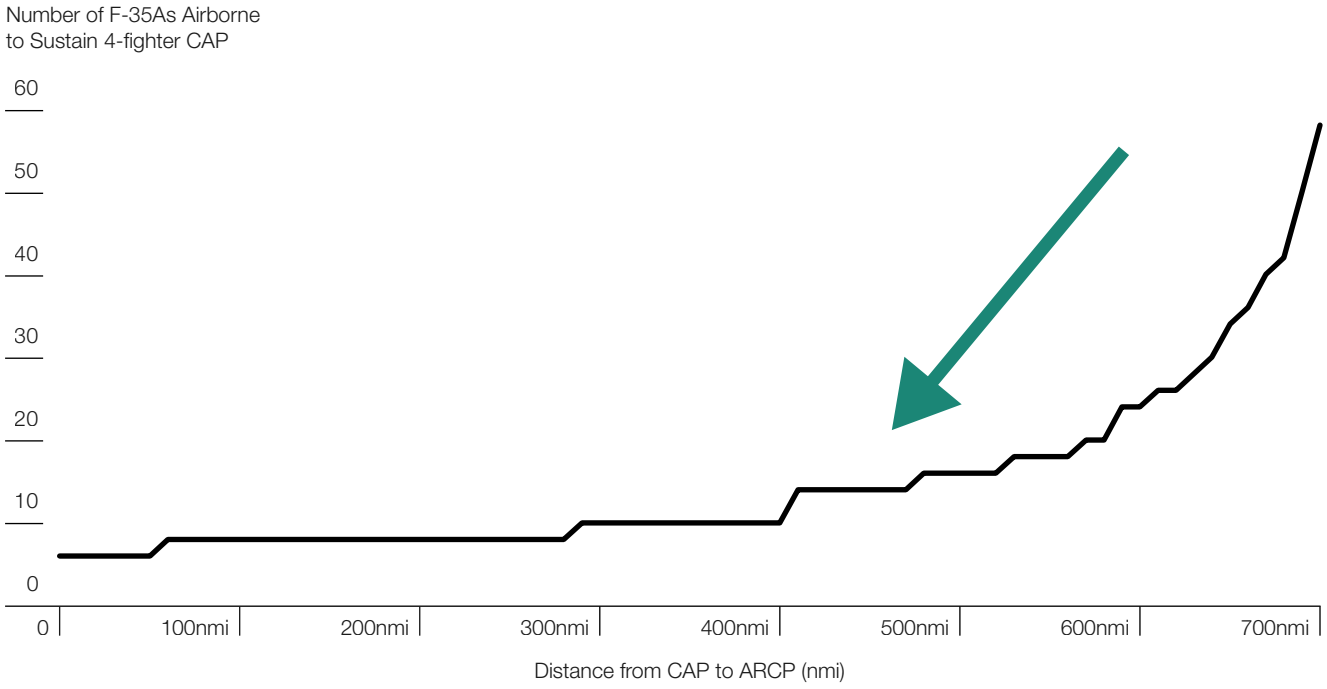
Similarly, analyzing the performance of tankers in vignettes set in the Pacific, North America, Europe, and the Middle East reveals that the Medium BWB provides the greatest performance and cost improvement. We examined 32 short-, medium-, and long-range vignettes requiring different levels and frequency of fuel offloads (a selection of which are shown in figure 4.10). On average, across these vignettes the Medium BWB required 30 percent fewer tankers, needed almost half as much tanker fuel, and had a 39 percent lower program average unit cost (PAUC). It also required a little more than half as much ramp space as the KC-46A, which in turn reserves more airfield space for other aircraft or for greater dispersion or hangar housing of the same aircraft. In general, other tanker options required more aircraft and cost more.

Enabling Contested Airspace Refueling with Shuttle Tanking

Efficiently refueling receiver aircraft, including over long distances, is not the only challenge facing the aerial refueling force. Tankers could be attacked in the air over long ranges, which could compel current tankers to stand back so far from threats (as seen in figure 2.3) that receiver aircraft must spend a great deal of time transiting back and forth from tankers. In turn, they would have little time on station (and require more receiver aircraft to perform the same mission) or could not execute the mission at all.

Figure 4.12 illustrates how the number of F-35As required airborne to support a single continuous four-fighter combat air patrol (CAP) grows from a modest eight fighters to an astounding 58 fighters as the distance from the CAP to the ARCP increases. Conversely, tankers that can approach to 300 nmi from the CAP would require 14 fewer fighters airborne to support the four-ship CAP than those that stand 600 nmi off. In short, addressing this force package–tanker standoff problem is imperative because tankers' inability to reach relevant operating areas could slash the effectiveness of Combat Air Forces aircraft in contested airspace.

Figure 4.12. Number of F-35As Airborne to Sustain a Four-Fighter CAP



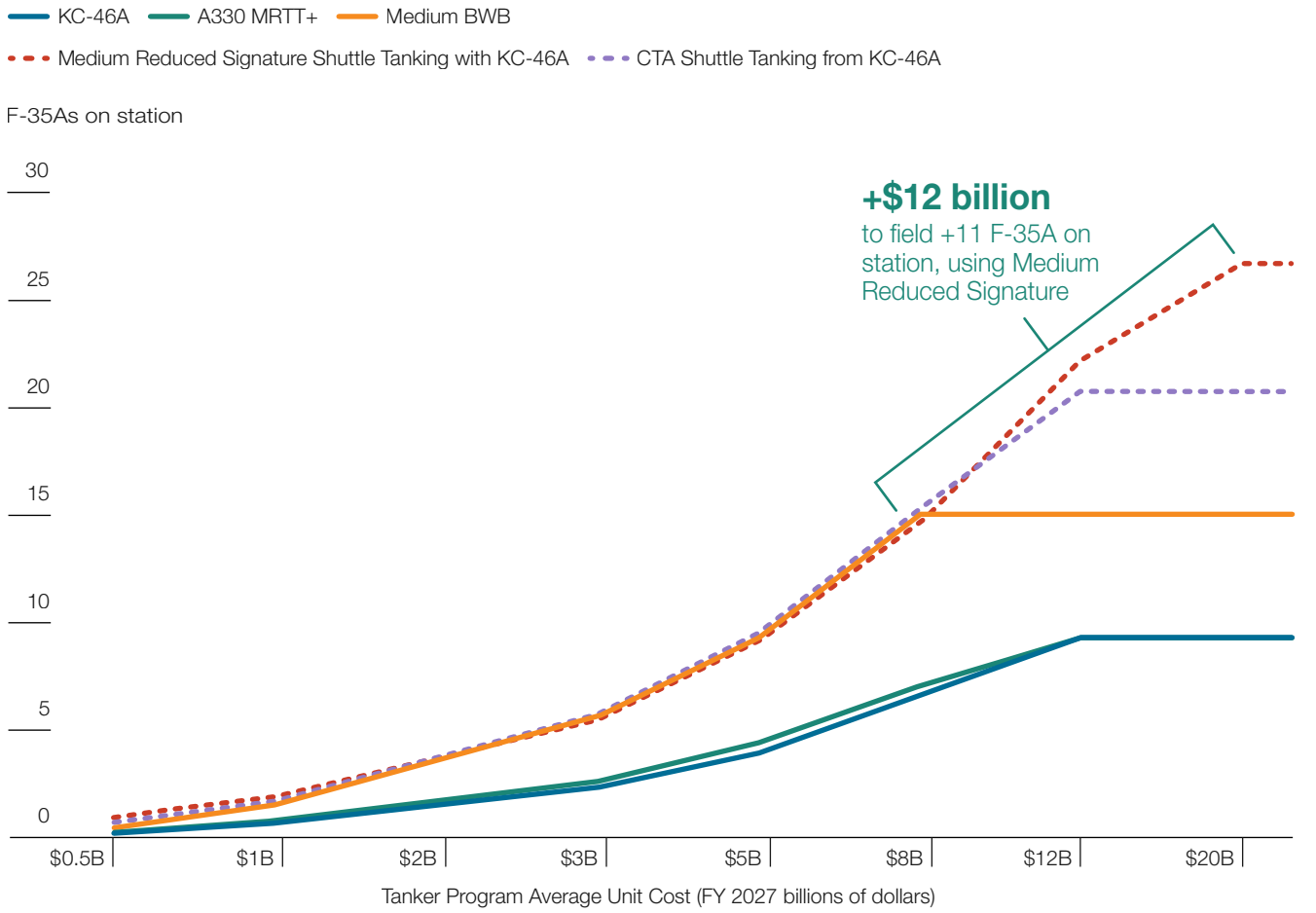
Source: Authors.

Note: Fighter requirements are derived by assuming 70 percent operational availability, two-hour turn times, eight-hour maximum flight time, two ships of F-35As that work to support the four-ship CAP, and fighter basing 500 nmi from the ARCP.

In response, shuttle tanking seems to offer a solution. Reduced-signature, risk-worthy, or attritable tankers could work with parent KC-46As or KC-135s to penetrate and persist inside contested airspace and refuel receiver aircraft. This approach would provide receiver aircraft with tanking a short-to-moderate distance away from their operating areas, helping maximize their fuel states and allowing them to execute tactics that require more range or endurance. It would also keep parent tankers safe in the air outside contested areas and reduce the number of receiver aircraft necessary to perform the same missions, allowing commanders to execute more simultaneous missions to gain and maintain the operational initiative. Furthermore, if the child tankers that shuttle had long endurance, they could also operate from distant airfields (such as in the contiguous United States) to reduce their susceptibility to attack on the ground.

However, this approach has its downsides. First, aerial refueling is already a complex endeavor subject to friction and interdiction, and requiring even more tankers to perform the same mission would exacerbate that dynamic with cascading cumulative chained probabilities of failure. A planner could overcome disruptions in shuttle tanking by increasing the number of parent and child tankers operating forward so that they could redirect surplus capacity to address emergent demands. Future contested aerial refueling planning will need to proactively allocate such surplus sorties to address emergent demands, including attrition, even if operating in

Figure 4.13. Number of F-35As from Andersen Air Force Base on Station over Taipei vs. Tanker Budget



Source: Authors.

direct delivery mode. Moreover, there are opportunities to improve aerial refueling efficiency through the automation of tanker-receiver pairing and other capabilities.[87] However, even the relatively small, unmanned CTA costs an estimated $80 million each. Given the cost of most tanker designs, it will be difficult to "flood the zone" with child tankers, much less even more expensive parent ones. Therefore, aerial refueling planning and design will need to make efficient use of limited tankers.

Second, in shuttle tanking, child tankers act as a range extension of parent tankers. Hence, if medium-range parent tankers such as KC-46As are vulnerable on the ground, regardless of how survivable child tankers are in the air, an enemy can suppress aerial refueling operations. The parent tankers could force-extend from distant airfields to reduce their own risk on the ground. However, even greater complexity then becomes necessary to execute the operation, and the virtual attrition tax reduces the effective capacity of the entire force.

And third, reduced-signature shuttle tankers are likely expensive to develop and procure. The general trend is evident in the estimated cost of our Medium Reduced Signature concept design. Using reduced signature shuttle tankers, it is also generally more expensive to maintain an equivalent number of receiver aircraft on station, when basing parent tankers at intermediate-to-distant airfields, than to maintain alternatives that can stand in a modest distance. This becomes apparent in small-scale mission vignettes and at the theater level. However, there could be exceptions to this trend, such as a small fleet of reduced signature aircraft that are relatively low-cost to develop and field and acquired for a small mission set.

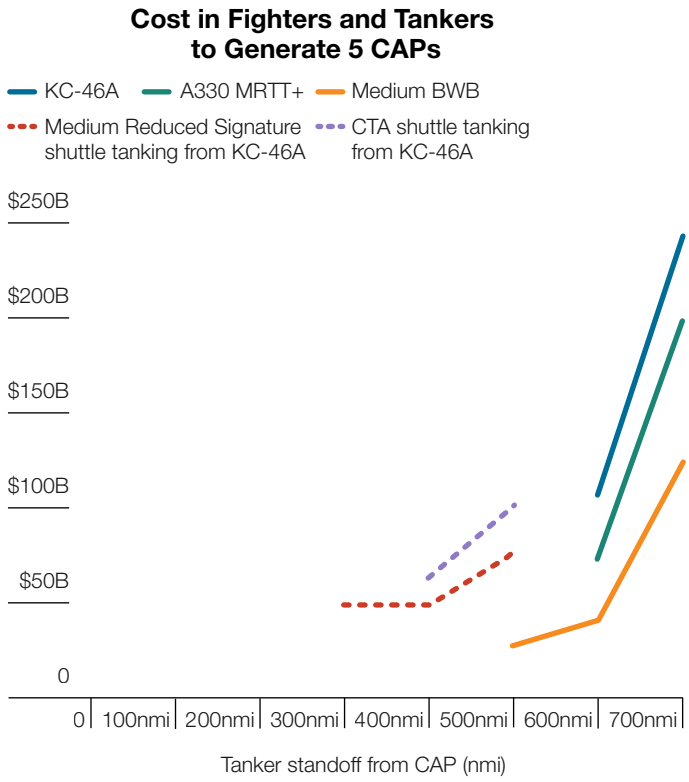
Figure 4.13 estimates the number of F-35As flying from Andersen Air Force Base in Guam that the Air Force can maintain on station over Taipei for a given tanker PAUC, with tankers also flying from that base. Even in this short-range (for the Pacific) vignette, given that the improved KC-46A and A330 MRTT+ must stand back 600 nmi from the CAP (700 nmi from the coast of the PRC), they can generate up to nine F-35As continually on station from a wing of 72 F-35As, at a cost of $12 billion in tankers. By being able to stand in an additional 100 nmi through a robust self-defense suite (and, to a minor degree, passive signature management), the Medium BWB can generate six more F-35As on station for $4 billion less.

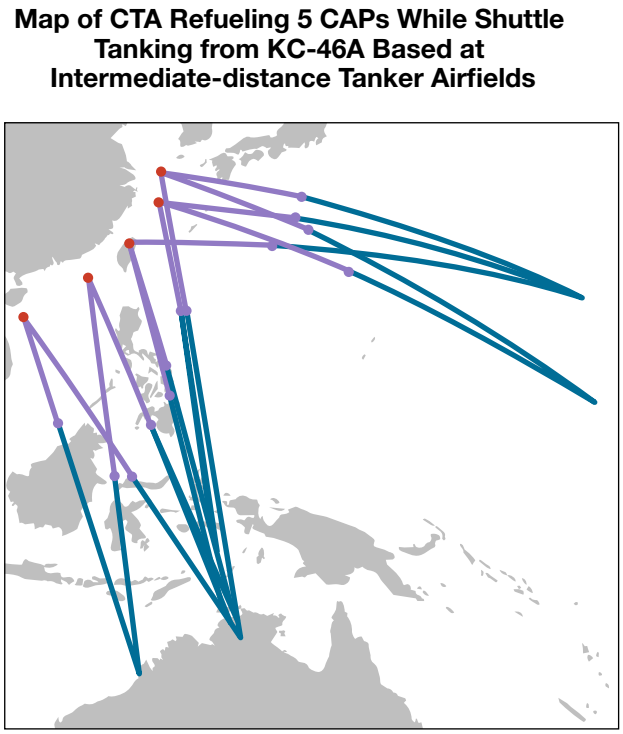
The child Medium Reduced Signature tanker that shuttle tanks from a parent KC-46A and can reach stand-back distances of 300 nmi from the CAP, and the child CTA that shuttle tanks from a parent KC-46A and can reach stand-back distances of 400 nmi from the CAP, can both further increase the number of fighters on station. Staying airborne for 72 hours, these unmanned shuttle tankers can penetrate and persist deeper into contested airspace than the Medium BWB. In turn, they can generate more fighters on station and could significantly enhance the tactical performance of fighters by enabling operations at a higher fuel state. However, they require a substantial investment of more parent KC-46A and child tankers to do so. For $8 billion in tanker investment, Medium BWBs operating in a direct delivery mode can generate 15 F-35As on-station, but generating 11 more F-35As on station (a total of 26 F-35As on station) with Medium Reduced Signature tankers costs another $12 billion in tankers. Consequently, reduced signature shuttle tankers would be valuable in extending the effective reach of combat aircraft, but depending on their attributes, these advanced aircraft could come at a considerable cost.

This dynamic is even more evident at larger scales and longer ranges, where the range and parking space limitations of the parent KC-46As make shuttle tanking options generally more expensive. Figure 4.14 shows the cost in fighters and tankers to sustain five CAPs in the First Island Chain from intermediate-distance tanker airfields. Within the figure, tankers conduct direct delivery or force extend as dynamically appropriate, and shuttle tanking designs receive fuel from direct delivery or force extended parent tankers and stay airborne for 72 hours. Assuming Medium BWBs can refuel 500 nmi from CAPs (or other desired operating areas, such as strike or sweep locations), and Medium Reduced Signature aircraft can penetrate to 300 nmi, it costs Medium Reduced Signature tankers $21 billion more in total fighter and tanker costs to generate the five CAPs. Even if Medium BWBs could only fly to 600 nmi from CAPs, it would still cost $7 billion less to refuel the CAPs. If Medium Reduced Signature tankers could not practically penetrate to 300–400 nmi due to factors such as air or naval threats along their route from parent tankers, then the cost differences become even greater. Furthermore, generating the five CAPs using medium-range KC-46As and A330 MRTT+s is considerably more expensive, since they require multiple tankers force extending to effectively operate at intermediate distances. Larger-scale analyses, such as supporting 10 or 15 CAPs, make the cost difference even greater, as medium-range tankers require even more ramp space and more distant airfields to support the same operations, thus further increasing cost.

There are short-range, small-scale cases in which the cost to generate effects with Medium Reduced Signature aircraft

Figure 4.14. Cost to Sustain Five CAPs of F-35A from Intermediate-Distance Tanker Airfields





Source: Authors.

Note: In this analysis, fighter airfields are modeled as located 500 nmi from ARCPs.

working with KC-46As is less expensive than Medium BWBs, and a Medium Reduced Signature design would certainly be more survivable than a moderate- or high-signature tanker. In general, though, our analysis shows that at the mission and theater levels, shuttle tanking is considerably more expensive, and the greatest gains in receivers on station come from being able to fly another 100–200 nmi closer to threats. In general, the Air Force should pursue future aerial refueling capabilities that increase the optionality of its tankers and receiver aircraft rather than forcing them to follow even more complex and brittle approaches.

Furthermore, from a broader force architecture view, this conclusion underscores the importance of Combat Air Forces capabilities that enable firing longer-range weapons and organically flying longer distances without aerial refueling. These measures would likely make forces more lethal and flexible and meter the demand for aerial refueling in highly contested or contested airspace.



5. EVALUATING TANKER PERFORMANCE UNDER ATTACK

To assess the ability of various tanker options to effectively support forces, we conducted theater-level simulations of a circa 2035 Taiwan invasion. For more information on the scenario, please see Walton and Patt's report *Flipping the Script: Redesigning the US Air Force for Decisive Advantage*.[88] Although the Air Force is unlikely to field most future aerial refueling aircraft design concepts in large numbers by 2035, we selected that year as "near enough to have a moderate degree of confidence in projecting US and PRC capabilities." Scenarios set further in the future, such as 2040 or 2045, would likely feature even more significant PLA attack capability and capacity but could also feature countervailing improvements in US and allied capabilities. Furthermore, "we selected a Taiwan invasion scenario as a highly stressing, consequential scenario that is reportedly DoW's lead defense planning scenario."[89]

"An attempted PRC invasion of Taiwan is idiosyncratic: US and allied forces would need to destroy large numbers of PRC forces, on short notice, in a small window of time, and near the PRC."[90] Yet there are similarities between a Taiwan invasion and other challenging scenarios involving the PRC, such as a Taiwan blockade or defense of allied territory. Other challenging

Photo: US Air Force Tech. Sgt. Katlin Hubbard, 351st Air Refueling Squadron boom operator, fuels an F-16 Fighting Falcon, assigned to the 31st Fighter Wing, during a mission over Italy on January 13, 2026. (US Air Force)

trans-Eurasian scenarios against Russia, and to a lesser degree scenarios involving Iran or North Korea, would also have some capability and capacity similarities with PRC scenarios, albeit at lower levels. Moreover, any PRC or Russia scenarios would require US forces to simultaneously maintain strategic deterrence, defend the homeland, and project power against the major adversary and potentially against other actors, and in response to other demands.

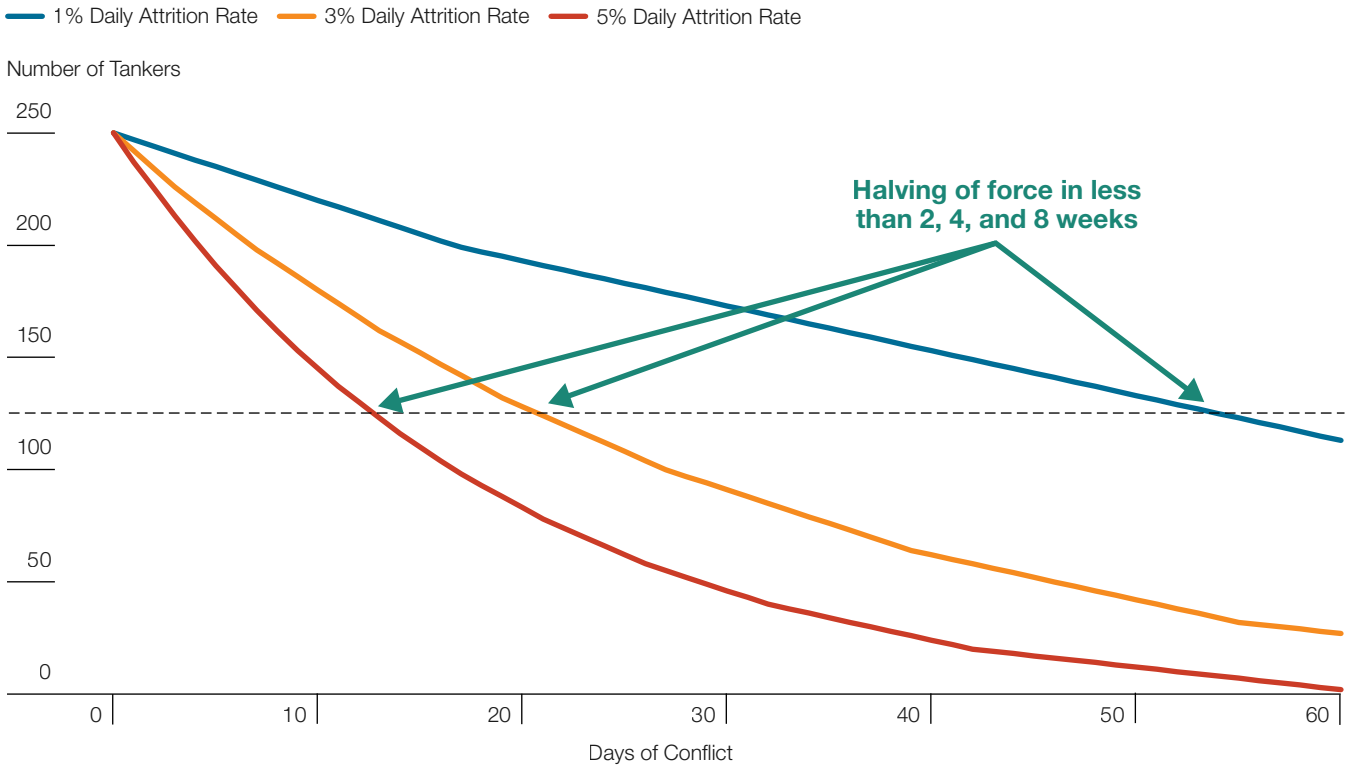
In a fight against the PRC, the aerial refueling fleet would need to generate enormous scale to address simultaneous demands across the operating theaters, provide options to commanders that allow them to fight forces effectively in different ways, and ensure the resilience of operations under attack. As seen in figure 1.2, the aerial refueling fleet requires capacity. It also requires new types of tankers to fight effectively against the PRC.

Overcoming Threats

In contrast to previous conflicts and planning scenarios, large-scale attrition of the tanker fleet is a major concern in a PRC scenario. The PLA could attack tankers and their supporting surface infrastructure on the ground and in the air, suppressing operations, destroying tankers, and killing crews. The aerial refueling fleet is large, but it is not sized to sustain high levels of attrition over a protracted period.

Recognizing the potential impact of attrition and other growing demands on force sizing, the US Congress mandated an in-

Figure 5.1. Impact of Daily Attrition Rates on Force of Tankers



Source: Authors.

crease in the minimum size of the tanker fleet from 466 to 502 aircraft by FY 2029.[91] This significant but modest 7 percent increase supports the near-term ability of the force to conduct large-scale conflict operations and sustain healthy deploy-to-dwell ratios. Nonetheless, it does not obviate the need to operate the force in a manner that minimizes attrition.

This phenomenon is not unique to the tanker fleet. As John Stillion and Bryan Clark observed:

> The necessity to fly many combat sorties with relatively scarce and expensive combat aircraft makes air forces extremely sensitive to even seemingly small loss, or attrition, rates. For example, a 1 percent per sortie attrition rate during Operation Desert Storm would have resulted in the loss of 518 of the approximately 2,200 coalition combat aircraft available at the start of the conflict (roughly 23 percent). Actual coalition combat losses were just 38 (0.07 percent per sortie). This highlights clearly why air forces have historically been extremely sensitive to combat loss rates and why they are willing to devote significant effort and resources to minimizing them.[92]

In a force of 250 tankers committed to support operations in contested areas of a conflict, even a seemingly low 1 percent daily attrition rate would halve the force in less than eight weeks, while higher rates would decimate it even faster (as shown in figure 5.1).

Against the PRC, attrition in the air is a major concern. PRC threats can and will be able to engage tankers at very long ranges. In response, broad-area counter-C5ISRT capabilities, long-duration surface and air-launched decoys that mimic the signatures of tankers and other aircraft, and friendly counter-air capabilities could thin threats and generate operational access for tankers.

Tankers will still be at significant risk, though, from dynamic and emergent long-range threats that will be difficult to fully suppress or neutralize. In response, robust tanker self-defense capabilities, new survivability systems onboard tankers, and some passive signature management or reduction could enable them to operate at acceptable levels of risk at appropriate standoff distances that enable receiver aircraft to execute their missions. Tankers with lower signatures and more robust defenses could operate closer to threats, while tankers with higher signatures and less robust defenses would need to stand off further.

The greatest threats against tankers are on the ground. As discussed in chapter 2, the PLA will be capable of attacking airfields that support bulk fuel and other surface infrastructure and tankers on the ground at an enormous scale and level of intensity. It will likely sustain the ability to fire thousands of munitions per day—especially near the PRC, such as within the First and Second Island Chains for a significant period. This applies even without accounting for additional attacks by PLA naval forces, special forces, or other units.

Given the PLA's focus on systems destruction warfare and nodal analysis, tanker airfields would likely be prime targets. Tankers require bulk fuel stores, long runways, and ample ramp space. All of these resources would be easier to suppress and more difficult to reconstitute than operations for other assets, such as fighter aircraft or runway-independent Edge Force units. There are also currently few hardened large aircraft shelters suitable for tankers, which makes them vulnerable to observation and attack on the ramp.

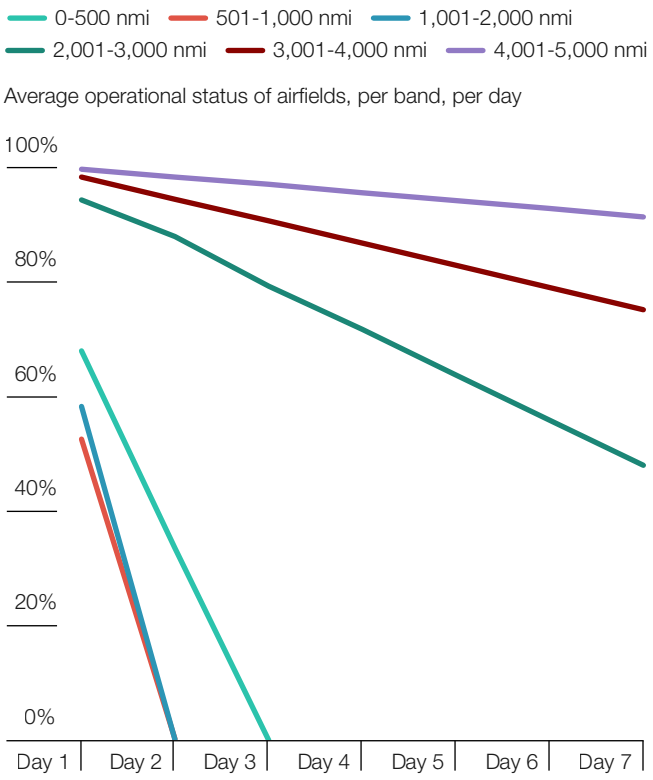
As shown in figure 2.8, we simulated the likelihood that the PLA can suppress tanker operations from airfields in 2035. We found that, even when accounting for powerful US and allied passive and active defensive capabilities and access to all tanker-suitable airfields on US and allied territory in the Indo-Pacific, the PLA may be able to suppress tanker operations from all potential tanker airfields in the First and Second Island Chains as well as in the Republic of Korea and Thailand within one

week. Intermediate-distance airfields in Diego Garcia, northern Australia, Wake Island, and Alaska would each also have an approximately 50 percent likelihood of being suppressed for tanker operations, and even distant airfields would likely come under attack but have a much higher likelihood of remaining operational. In our analysis, we conservatively assumed that strikes with a requisite number of munitions and destruction of their bulk fuel stores would put airfields out of operation for the duration of our analysis for large-scale tanker operations.

In practice, US and allied forces would likely adopt approaches that thin the level of threats and ensure continued tanker operations from some of these forward airfields, despite enemy attacks. Moreover, if properly prepared and garrisoned, many of these airfields could likely reconstitute from attacks relatively quickly and sustain operations for fighters or other aircraft, and more slowly for tanker aircraft. Nonetheless, the analysis revealed the potential scale and scope of future PLA strikes and their severe impacts.

It also illuminated two major insights relevant to tanker employment and design. First, as seen in figure 5.2, airfields in the 1,001–2,000 nmi geographic band encompassing the Second Island Chain counterintuitively had on average a lower rate of operational status for tankers (as opposed to being suppressed) compared to closer-to-China airfields in the 0–500 nmi band, despite being significantly farther and facing thousands fewer munitions. The difference is due to the planned presence by 2035 of only three airfields suitable for sustained tanker operations in the Second Island Chain (Andersen Air Force Base, Antonio B. Won Pat International Airport, and Tinian International Airport) compared to 13 in the 0–500 nmi band. This suggests planners will need to be able to continuously operate some tankers from First Island Chain airfields or at least be able to drop in and hot-refuel tankers, given the proximity of the First Island Chain to desired receiver operating areas and the possibility that some of these airfields remain operational longer than ones in the Second Island Chain.[93]

Figure 5.2. Average Rate of Operation of Airfields in Geographic Bands per Day



Source: Authors.

Second, and most importantly, our simulation showed that the PLA is far more likely to suppress forward airfields in the First and Second Island Chains for tanker operations than to suppress intermediate and distant airfields. The attacks could negate the ability to operate at scale from those airfields and destroy large numbers of tanker aircraft on the ramp. Consequently, in terms of the aerial refueling fleet, the Air Force should embrace operational approaches that employ most of its tankers from intermediate and distant airfields and preferentially improve the surface infrastructure of those locations. It should also develop and procure long-range, high-offload tankers that can effectively operate from intermediate and distant airfields.

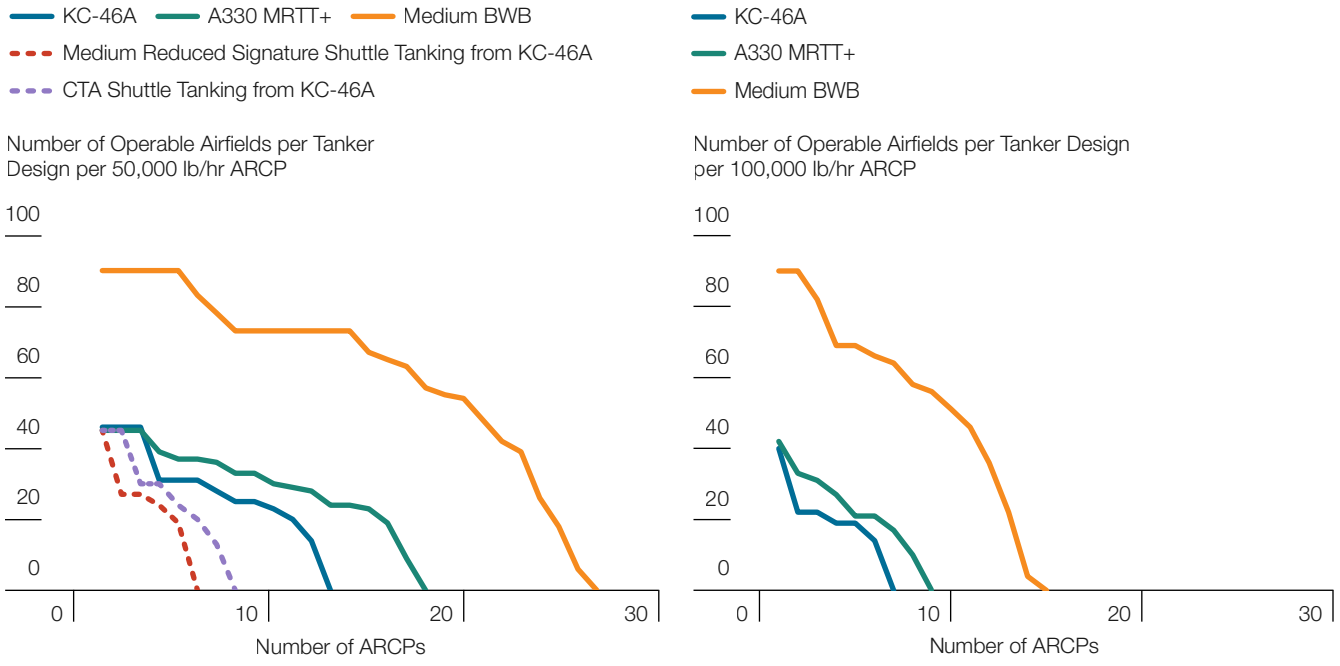
Comparing Theater-Level Performance Under Attack

To compare the performance of tanker options in the circa 2035 scenario, we assumed the tanker fleet would operate from laydowns where it would be subject to aircraft attrition on the ramp of 1 percent or less of the committed force per day. As seen in figure 5.1, this is a significant level of attrition, and any higher rate may not be sustainable for a significant period.

Conducting simulations, we then generated potential airfield laydowns with up to 200 tankers for each of the five representative tanker designs in support of ARCPs in the Western Pacific. We used algorithms that allowed tankers to fly direct delivery, force extension, or direct delivery or force extension followed by shuttle tanking mission profiles. To minimize the risk of attack on the ground, shuttle tanking Medium Reduced Signature and CTA tankers were assumed to stay airborne for 72 hours and fly from contiguous United States airfields.

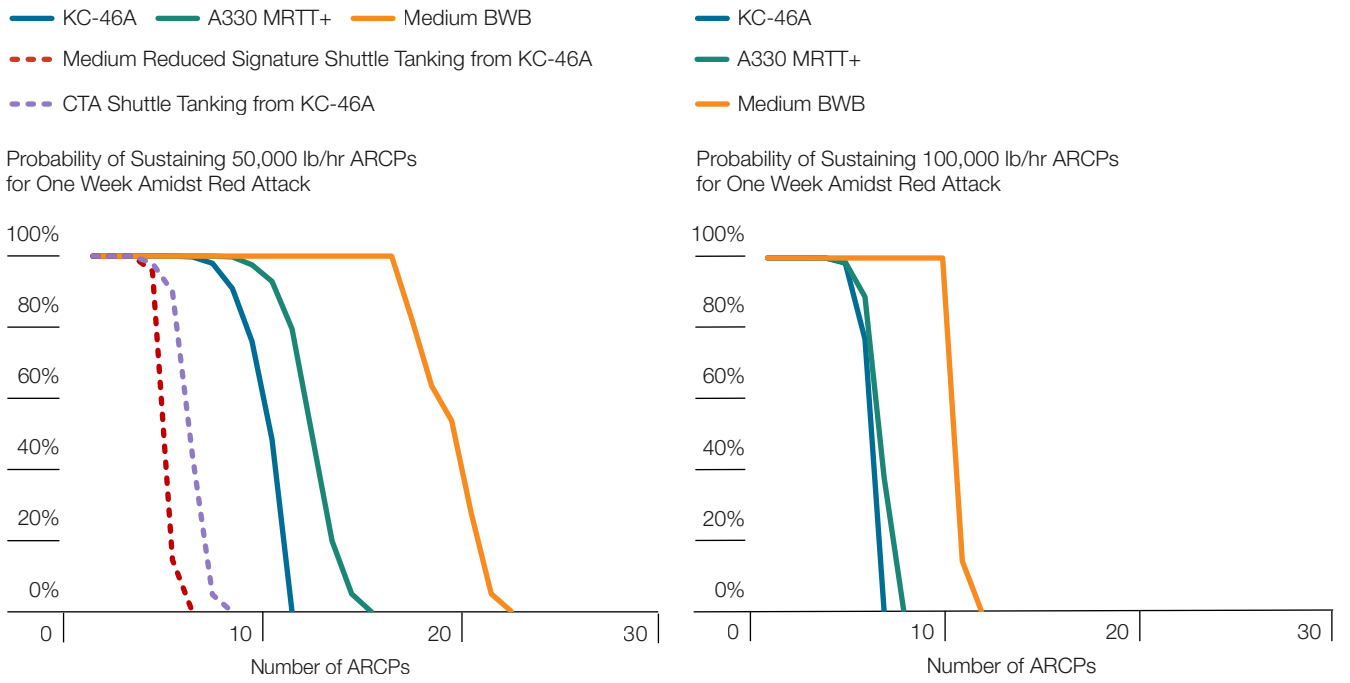
In terms of optionality, figure 5.3 shows the total number of potentially operable airfields at each desired number of ARCPs while keeping aircraft attrition on the ramp at 1 percent or less of the committed force per day.[94] More airfields are preferable, as they provide commanders with more options from which to conduct operations and make it more challenging for an adversary to destroy tankers on the ramp and suppress operations. In the simulations, the KC-46A and A330 MRTT+ generally force-extended to fly from airfields where ramp attrition was low to moderate. They could support 14–17 continuous 50,000 lb/hr ARCPs. The Medium Reduced Signature and CTA—both shuttle tanking from largely force-extended KC-46As—could support even fewer ARCPs. The long-range, high-offload Medi-

Figure 5.3. Airfield Operability by Tanker



Source: Authors.

Figure 5.4. Ability to Generate ARCPs over One Week



Source: Authors.

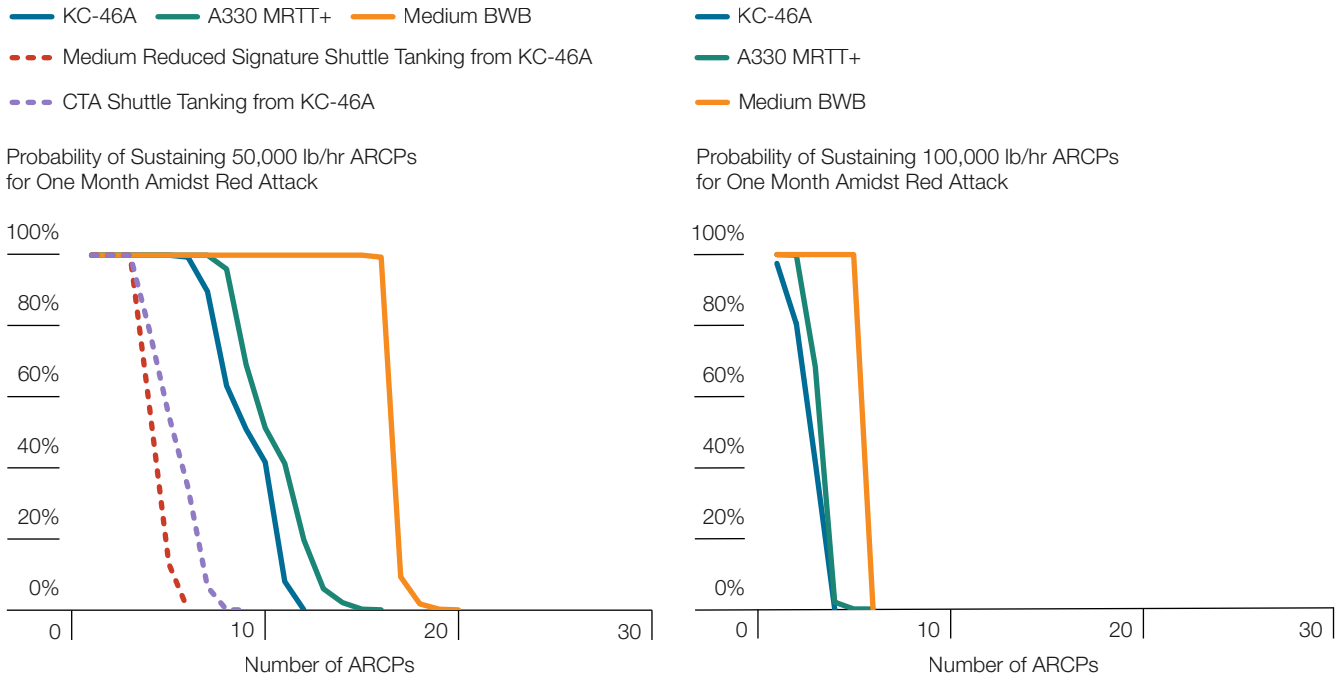
um BWB could sustain up to 26 ARCPs and operate from twice as many airfields. In terms of servicing 100,000 lb/hr ARCPs, shuttle tanking was no longer viable at scale, and the KC-46A and A330 MRTT+ could only sustain six and eight ARCPs, respectively. The Medium BWB is able to sustain up to 14 and can operate from more than twice as many airfields.

Simulating the generation of ARCPs amidst PLA attack in figure 5.4, we find that over a one-week period, the KC-46A and A330 MRTT+ have a 90 percent probability of sustaining eight and ten continuous 50,000 lb/hr ARCPs, respectively. A Medium BWB could sustain 16 ARCPs, and the shuttle tanking options could sustain only four to five ARCPs at a 90 percent probability threshold. In terms of continuous 100,000 lb/hr ARCPs, the KC-46A and A330 MRTT+ could sustain five, while the Medium BWB could sustain ten.

If the simulation is extended to one month, though, their ability to sustain operations is slashed, as shown in figure 5.5. The KC-46A and A330 MRTT+ support only seven and eight continuous 50,000 lb/hr ARCPs, respectively, while the Medium BWB can sustain 16. In terms of continuous 100,000 lb/hr ARCPs, the KC-46A and A330 MRTT+ could respectively support one and two ARCPs, while the Medium BWB can support five. This demonstrates how, given its long range and high offload capacity, the Medium BWB can operate in a highly resilient manner from forward, intermediate, and distant airfields and remain relatively insensitive to enemy airfield strikes.

All five tanker options can be operated in ways that reduce their risk on the ground to acceptable levels. However, for the KC-46A and A330 MRTT+ (and for the Medium Reduced Signature

Figure 5.5. Ability to Generate ARCPs over One Month



Source: Authors.

and CTA that depend on the KC-46A), flying from intermediate and distant airfields using force extension comes at a considerable cost, supporting fewer ARCPs. Consequently, if commanders needed more refueling capacity and distribution than the modest levels these designs could provide, they would be forced to push their tanker basing closer to threats and thus accept likely unsustainable levels of attrition on the ramp. A long-range, high-offload design such as the Medium BWB that can fly using direct delivery and force extension from distant airfields (as well as access forward and intermediate ones when appropriate) provides far greater capacity, operational flexibility, and resilience.

The range and offload limitations of current tankers were at play in *Flipping the Script* simulations of a circa 2035 conflict with the PRC. As Walton and Patt write:

> To limit attrition on the ground, most of the KC-46A and KC-135 tankers committed to the campaign had to fly from intermediate and distant airfields in Australia, the Central Pacific, Alaska, and beyond (in direct flights and using force extension), in addition to a portion of the tanker fleet that operated from in and around the First and Second Island Chains. On average these long-distance operations reduced the tanker fleet's effective offload capacity.[95]

Furthermore:

> Medium-sized BWB tanker concepts greatly outperformed other refueling design concepts we separately evaluated, including ones in which small or medium-sized stealthy tankers shuttled back and forth

Table 5.1. Performance of Select Alternative Tanker Fleets in Taiwan Invasion Scenario Compared to Blue 1 "Baseline" KC-46A and KC-135 Force

TANKER FLEET OPTIONS	RECEIVER SORTIES THAT DESIRE AERIAL REFUELING THAT CAN BE ADDRESSED BY TANKERS	RED:BLUE AIRCRAFT LOSS RATIO	RED AMPHIBIOUS VESSEL LOADS LANDED ON TAIWAN
Alternative 1: KC-46A and Medium-sized BWB	+46%	+38%	-5%
Alternative 2: KC-46A and Shuttle Tanking Medium-sized Reduced Signature	-7%	+19%	+12%
Alternative 3: KC-46A and Shuttle Tanking Collaborative Tanker Aircraft	+1%	+13%	-1%

Source: Walton and Patt, *Flipping the Script*, 106. For more information on the simulation, see the endnote.[97]

from KC 46A. Compared to alternative design classes, medium-sized BWB could access 1.4–2 times as many airfields, deploy farther and faster with less mobility aircraft support, refuel at least 2.5 times as many force packages, sustain operations the longest amidst airfield attacks, and [as shown in table 5.1], improve campaign success and Red:Blue aircraft loss ratios the most in this study's Taiwan invasion scenario.[96]

Aerial Refueling Support to Force Deployment

Another major theater-level demand for aerial refueling is force deployment. A large-scale overseas crisis would require tanker aircraft to refuel other aircraft deploying to and from theaters of operation. The availability, distribution, and capacity of the aerial refueling fleet significantly shape how many and how quickly forces can deploy. The speed of deployment affects success in a variety of scenarios, ranging from HA/DR to large-scale conflicts, and it is one of the most vexing problems facing deterrence and warfighting in potential scenarios involving the PRC.

Upon indications and warning of potential PRC aggression, the US president may order the deployment of additional forces and supplies to operating areas in the Indo-Pacific to deter aggression. However, this deployment decision, which the DoW commonly refers to as "flowing the Time-Phased Force and Deployment Data (TPFDD)", carries significant risk since the PRC could then decide to accelerate its decision-making or attack timeline to achieve a fait accompli before US forces deploy. The PRC could also preventively attack deploying US forces and infrastructure before they are ready to operate in the theater.[98] As a result, more forces could help deter aggression, but slow deployments could be crisis-destabilizing since they may incentivize aggression before US forces are set in a theater rather than deter it.

To address this dilemma, US defense leaders have considered multiple options:

- Prepositioning forces, equipment, and supplies forward in the theater so that they do not require rapid deployment in a crisis

- Fielding more capabilities, such as long-range bombers and cargo aircraft with palletized munitions (referred to as Pulsed Forces) that the US can directly employ over long ranges to generate combat power, rather than needing to first deploy to then employ
- Accelerating TPFDD timelines by either requiring delivery of fewer forces and supplies or speeding up their delivery[99]

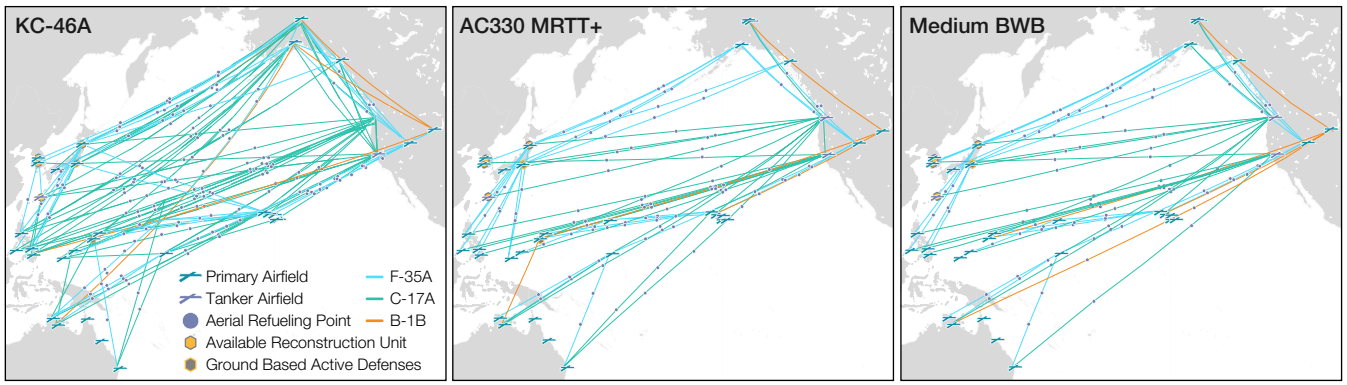
Aerial refueling plays a vital supportive role in the employment of Pulsed Forces and speeds up the deployment of other forces and delivery of supplies by ensuring adequate aerial refueling is available to enable faster, nonstop or limited-stop flights.

In a forthcoming report, Timothy A. Walton, Shane Dennin, and Sean Maxfield examine infrastructure, defenses, and logistics options to improve the ability of US forces to deploy to the Pacific.[100] Simulating a circa-2035 crisis with the PRC (Red), they executed a notional, simplified TPFDD of US forces (Blue) involving the deployment of 500 F-35As to 20 destination airfields, 50 B-1Bs to four destination airfields, and 42 loads of 130,000 lb of cargo to each of 20 destination airfields using 150 C-17As (or other mobility aircraft options). One hundred tanker aircraft (KC-46A, A330 MRTT+, or Medium BWB) were available to refuel these aircraft over the simulation's maximum timeline of 30 days. Figure 5.6 shows the paths the F-35As, C-17As, and B-1Bs took to reach destination airfields. The higher-load and longer-range A330 MRTT+ and Medium BWB facilitated longer, more direct routes.

As shown in table 5.2, aerial refueling played a major role in the performance of forces. Higher-capacity, longer-range aerial refueling options (to a lesser degree, the A330 MRTT+ and to a much greater degree, the Medium BWB) greatly accelerated the speed and increased the number of successfully deployed aircraft and delivered cargo loads. The A330 MRTT+ and Medium BWB were respectively able to refuel 1.0–1.5 and 1.6–2.1 times as many contacts per day as the KC-46A.

These differences were pronounced in simulation runs in which no enemy contested the force deployment; the A330 MRTT+

Figure 5.6. Deployment Tool Visualizer of Uncontested Deployment Runs



Note: The longer range and higher offload of the A330 MRTT+ and, to a greater degree, the Medium BWB enable more direct, nonstop flights from the contiguous United States to destination airfields and vice-versa. In the above A330 MRTT+ and Medium BWB maps, this is reflected in fewer blue (F-35A), orange (B-1B), and green (C-17A) lines going through en route airfields in Alaska, Hawaii, and the Marianas compared to the KC-46A map that shows a heavy reliance on routes with en route stops.

Source: Walton, Dennin, and Maxfield, *Indo-Pacific Infrastructure and Logistics*.

Table 5.2. Performance of Tanker Options Supporting Force Deployments

SIMULATION AVERAGES	UNCONTESTED DEPLOYMENT Uncontested Results			CONTESTED DEPLOYMENT Red Attacks Begin on Day 8			CONTESTED DEPLOYMENT Red Attacks Begin on Day 2		
	KC-46A	A330 MRTT+	MEDIUM BWB	KC-46A	A330 MRTT+	MEDIUM BWB	KC-46A	A330 MRTT+	MEDIUM BWB
Percent of Aircraft Deployed	100%	100%	100%	66%	58% **0.9x**	70% **1.1x**	30%	31% **1.0x**	37% **1.2x**
Percent of Cargo Loads Delivered	100%	100%	100%	56%	63% **1.1x**	69% **1.2x**	21%	27% **1.3x**	29% **1.4x**
Days required to deploy an equivalent joint force relative to the KC-46A in a conflict with the PRC (Aircraft Deployed and Cargo Loads Delivered)	18	15 **0.8x**	13 **0.7x**	30	27 **0.9x**	13 **0.4x**	25	17 **0.7x**	11 **0.4x**
Number of aerial refueling contacts per day	284	416 **1.5x**	464 **1.6x**	141	143 **1.0x**	299 **2.1x**	91	122 **1.3x**	174 **1.9x**

Note: Average, rounded results of 1,000 simulation runs per option.

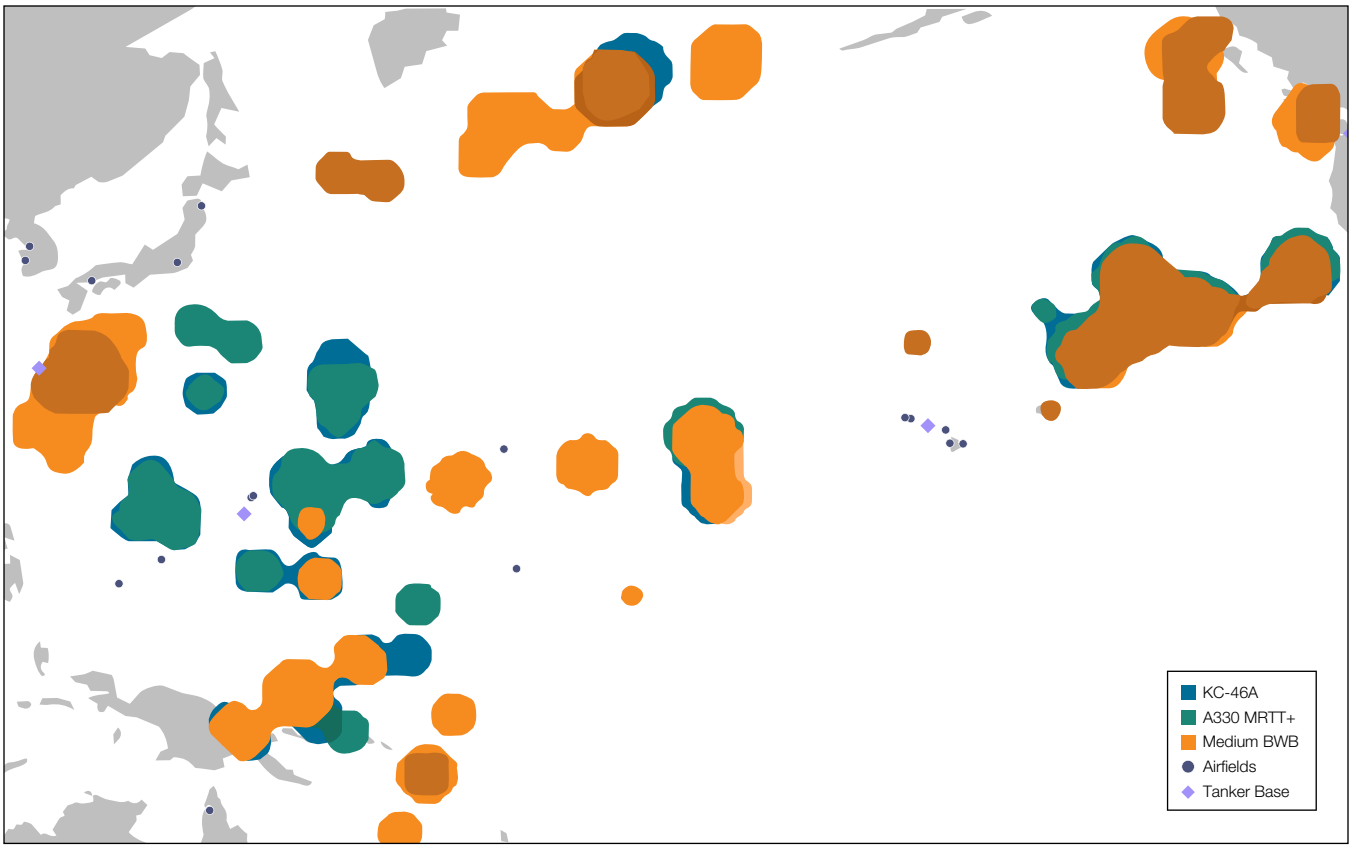
Source: Walton, Dennin, and Maxfield, *Indo-Pacific Infrastructure and Logistics*.

and Medium BWB cut deployment times by four and five days, respectively. They were stark in the simulations in which Red forces attacked Blue forces on Day 8 or Day 2 of the deployment. In these cases, the A330 MRTT+ and Medium BWB were able to deliver up to 40 percent more aircraft or cargo loads. The Medium BWB also delivered the KC-46A's baseline number of deployed aircraft or cargo in less than half as much time.

Beyond just speed, the Medium BWB allowed the force to maneuver differently. Its long-range, high-offload aerial refueling capacity allowed more and farther refueling (as shown in figure 5.7), which in turn made new routes viable. This fundamentally changed how forces could deploy to destination airfields by obviating the need to route through as many suppressible forward and intermediate airfields, and those where aircraft are destructible on the ramp or that take much longer to reach. Instead, Medium BWB support enabled many nonstop flights to destination airfields and greatly accelerated deployment timelines. By "exploding into the theater" with more capable aerial refueling, forces could emplace before the potential initiation of hostilities (and ideally deter conflict), reduce en route attrition, allow a much larger fraction of aircraft and cargo loads to reach destination airfields, and provide commanders with far greater optionality, flexibility, and resilience in deploying forces.[101]

Analyzing the simulation results also reveals the immense challenges of deploying forces under attack. As Red suppressed airfields, it became highly difficult for Blue to trans-Pacifically

Figure 5.7. Heat Map of Aerial Refueling Contact Points in the Uncontested Deployment



Note: Average result of 1,000 simulation runs.

Source: Walton, Dennin, and Maxfield, *Indo-Pacific Infrastructure and Logistics*.

deploy aircraft and deliver cargo loads despite the efforts of Blue airfield active and passive air defenses to defend airfields and reconstitution units to get them back in operation. At a high level, this and other similar insights should emphasize the importance of prioritizing resources for forward-deployed, runway-independent Edge Forces and long-range Pulsed Forces that can directly generate effects with moderate aerial refueling support. Nonetheless, across a range of contingencies including this one, rapidly deploying a significant number of Air Force and other service forces will be essential. Aerial refueling is a critical enabler of that capability, and long-range, high-offload aerial refueling aircraft can dramatically improve performance and provide commanders with more options for when and how to flow forces.



6. NECESSARY ATTRIBUTES OF FUTURE TANKERS

The aerial refueling fleet faces major challenges, and unless it rapidly changes, the US ability to maintain strategic deterrence, defend the homeland, and project power will be at risk. Examining mission and theater demands reveals necessary attributes of future tankers. They should be able to:

- **Deliver high offloads of fuel at long ranges.** This would reduce susceptibility to attack on the ground by enabling operation from intermediate and distant airfields. It would also enable large-scale and rapid Pulsed Force missions and force deployments and generate more endurance and maneuverability for a broad range of receiver aircraft, allowing them to operate in a more dynamic and distributed manner.
- **Access and operate from forward, intermediate, and distant airfields** to enable operational flexibility and challenge adversary targeting. This entails not only the ability to fly a long range, but also reasonable takeoff field lengths and pavement strength requirements to access airfields, as well as a moderate size to efficiently use valuable and contested ramp space.
- **Stand-in a modest distance (as opposed to standing off from or penetrating deep) into contested air environments** to reduce the number of fighters and other receivers required to conduct operations. Tankers should also have an appropriate level of survivability in that contested airspace.

Photo: US Air Force Maj. Simon Thaler, 14th Airlift Squadron C-17 Globemaster III pilot, conducts an aerial refueling with a KC-46 Pegasus during Exercise Palmetto Reach on January 14, 2026, near Hawaii. (US Air Force)

- **Exhibit high operational availability rates, limited ground support equipment requirements, and fast turn and scramble times** to maximize fleet usage and flexibility and minimize exposure and vulnerability to attack on the ground.

Although currently available, the KC-46A and A330 MRTT+ do not provide the most important necessary attributes for the next type of future tanker. Given their medium ranges, they must force-extend to operate at acceptable levels of risk from intermediate and distant airfields. And when they do so, they can support only a moderate number of forces for a limited time, which would hinder the joint force's ability to operate with distribution, scale, and tempo as well as protract a conflict. They could adopt enhanced C3 and self-defense systems to fly a bit closer to threats. However, many of these potential systems would likely impose weight and drag penalties that exacerbate offload-at-range limitations. The planform designs will also constrain the size, weight, power, and cooling of advanced self-defense systems. Consequently, over time these designs will likely face even greater challenges standing in an appropriate distance to refuel receiver aircraft.

Designs reliant on shuttle tanking to operate at scale, such as the Medium Reduced Signature and CTA concepts we examined, fail to address the fundamental range problem facing the tanker fleet. They could penetrate much deeper into contested airspace and greatly improve the tactical performance and efficiency of supported force packages of fighters; however, shuttle tanking operations would remain highly vulnerable to attacks on the forward and intermediate airfields from which parent tankers such as the KC-46A would fly. And if parent KC-46As introduced even more complexity and fragility into shuttle tanking by force-extending to support child tankers, then even less tanker capacity would be available to support these and other operations throughout the theater.

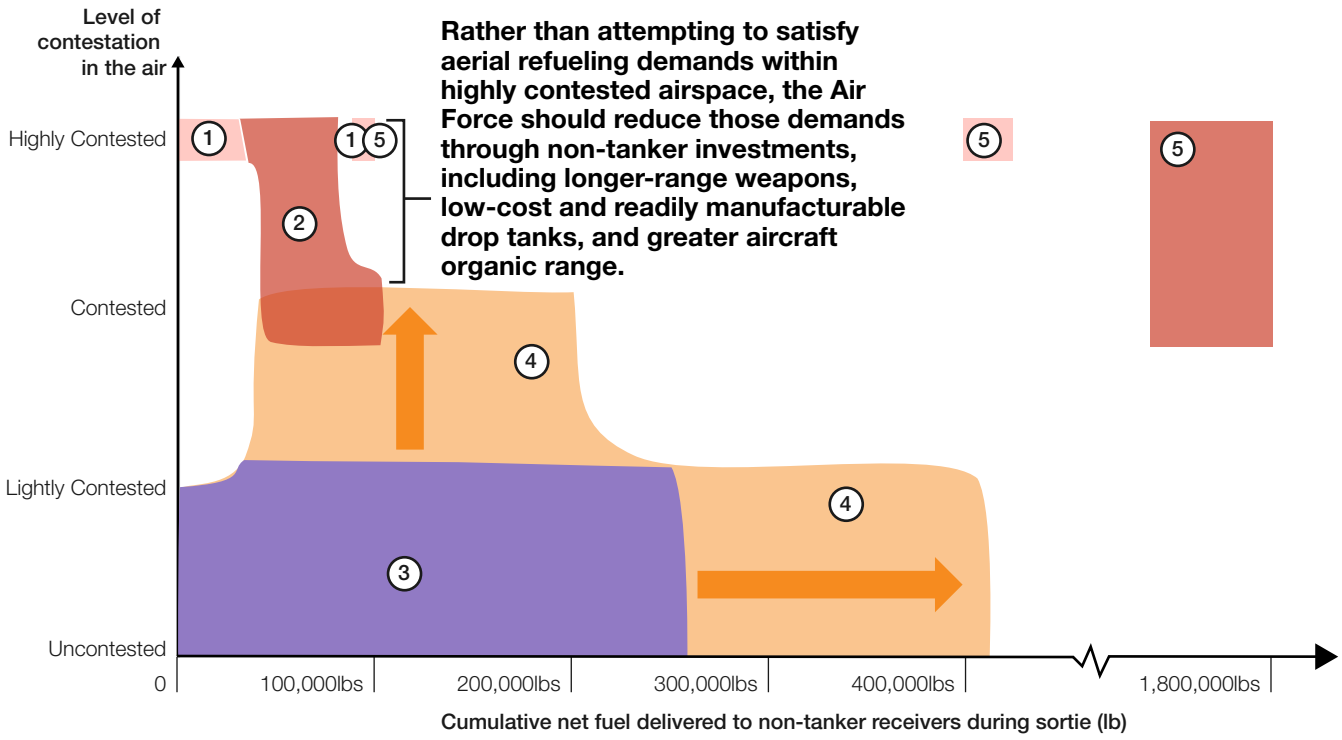
Other variations on the Medium Reduced Signature and CTA archetypes we examined could be pursued by the Air Force. Some of these may cost less to develop and field—especially if only a small fleet of aircraft were acquired to address a small set of demanding missions. However, such a fleet would only generate a low level of capacity, and shuttle tanking operations would continue to rely on parent tankers.

On the whole, adversary threats and friendly demands require aerial refueling solutions that generate greater optionality vice enhanced optimality for current or derived approaches. Rather than pursuing incremental improvements in performance, such as supporting a few more ARCPs or clawing back a bit more access, that enable slightly better ways to fight, future aerial refueling platforms should provide a discontinuous change that generates a massive increase in the optionality, lethality, and resilience of the joint force that enables new, more effective operational approaches.

A medium-sized, long-range, high-offload tanker such as a Medium BWB provides these necessary advantages. It could be significantly cheaper than the KC-46A, requiring fewer tankers, burning less fuel, and costing less to field and operate across missions. Given its new design and size, weight, power, and cooling margins, it could be equipped with a robust, integrated defensive suite (and to a minor degree, passive signature management) that exceeds the performance of retrofits to current tankers and enables it to fly closer to threats. Compared to alternatives, it could access 1.3–2 times as many airfields, refuel twice as many or more force packages, sustain protracted operations under attack, deploy forces 40–80 percent faster, and most improve campaign success and Red:Blue aircraft loss ratios. In support of the joint force, long-range, high-capacity Medium BWBs could create an abundance of aerial refueling that unlocks new standoff and penetrating concepts of operation; enables more dynamic, lethal, and resilient operations; and could help deter conflict or win if necessary.

As compact fuel transfer systems and refueling autonomy mature, the Air Force could consider other complementary refueling concepts, including kits that could convert commercial aircraft into tankers. This could provide a latent war reserve of tankers—especially to service low-to-moderate fuel demands in uncontested or lightly contested air environments.

Figure 6.1. Aerial Refueling Opportunities by Sortie Offload and Level of Airspace Contestation



1. Small attritable or risk-worthy penetrating shuttle tankers could deliver small quantities of fuel to receivers in Highly Contested Airspace.
2. Penetrating shuttle tankers could refuel in Contested or Highly Contested Airspace.
3. Current medium-range tankers operate in Uncontested or Lightly Contested Airspace. Through force extension (to include fuel consolidation), they occasionally deliver more fuel than their own tanker's capacity.
4. Medium-sized long-range, high-offload stand-in tankers could expand the refueling envelope beyond that of current tankers by enabling some refueling in contested airspace and, through greater organic capacity and force extension (to include fuel consolidation), higher aggregate fuel delivered over the course of missions.
5. Supported by parent tankers, child shuttle tankers of different sizes could conduct multi-day sorties that in aggregate deliver a great deal of fuel to receivers.

Source: Authors.

Another complementary concept is low-cost attritable or risk-worthy shuttle tankers. Supported by parent tankers, large numbers of these unmanned designs could potentially address low-volume demands in contested or highly contested airspace. However, refueling in highly contested airspace is challenging, and the design and certification of these systems is also likely to be demanding. At least in the near term, rather than attempting to satisfy aerial refueling demands within highly contested airspace, the Air Force should prioritize reducing those demands through non-tanker investments, including longer-range weapons, low-cost and readily manufacturable drop tanks, and greater combat aircraft organic range.



7. IMPLEMENTING AN EFFECTIVE AND RESILIENT AERIAL REFUELING FORCE

To field an effective and resilient aerial refueling architecture, the Air Force can take a holistic approach that appropriately resources elements of the entire aerial refueling architecture and can be achieved with either additional funds or by reprioritizing planned funds. As described in *Flipping the Script: Redesigning the US Air Force for Decisive Advantage*, our proposed plan could be pursued with additional resources or, with some delays, under a flat budget.[102]

Surface Infrastructure Improvements

By enhancing its surface infrastructure, the Air Force could ensure that tankers can operate at scale and, in turn, that supported forces can execute their necessary tasks. In the FY 2027 budget, the Air Force proposed increasing funding of military construction by $6.44 billion. This is a necessary step to address long-deferred infrastructure recapitalization.

In future budgets, the Air Force will need to sustain military construction funding levels to begin to shift from a force accustomed to uncontested operations on the ground to one that can sustain operations under attack. In particular, the Air Force should prioritize the surface infrastructure capacity and resilience necessary to sustain large-scale tanker operations from key, well-defended intermediate and distant tanker bases. These strongpoints will be necessary for aerial refueling to support a wide range of operations, including long-range bomber strikes, support for mobility aircraft deploying forces and supplies or directly delivering palletized munitions, and tanker bridges for fighters. Table 7.1 shows a representative set of po-

Photo: A US Air Force KC-46 Pegasus aircraft redeploys in support of Exercise Bamboo Eagle 25-3 at Andersen Air Force Base in Guam on July 31, 2025. (US Air Force)

Table 7.1. Representative Tanker Airfield Infrastructure, Fuel Storage and Distribution, Reconstitution, Other Passive Defenses, and Active Defenses

TYPE OF SYSTEM	NUMBER	COST (BILLIONS OF FY 2027 DOLLARS)
Large Aircraft Hardened Aircraft Shelters (3 per Regular Airfield)	60	$3.06B
Hardened Fuel Storage and Distribution (set of 3 50,000 bbl USTs or capped cut and cover tanks, pumps, and hydrants, 10 100,000 gallon expeditionary fuel bladders and pumps, 10 R-11 trucks, 2 IPDS, and 2 OPDS) (1 per Regular Airfield)	20	$5.19B
Expeditionary Fuel Storage and Distribution (set of 10 100,000 gallon expeditionary fuel bladders and pumps, 10 R-11 trucks, 1 IPDS, and 1 OPDS) (1 per Dispersal Airfield)	20	$0.93B
Small Bunker (10 per Regular Airfield)	200	$1.15B
Large Bunker (2 per Regular Airfield)	40	$3.82B
RADR Kits (2 per Regular Airfield; 1 per Dispersal Airfield)(one additional RADR/Civil Engineer or PRIME Beef unit per airfield)	60	$3.33B
Additional RADR Supply Sets (2 per Regular Airfield; 1 per Dispersal Airfield)	60	$0.61B
Passive Defense CCD Kit for Airfield (2 per Regular Airfield; 1 per Dispersal Airfield)	60	$1.74B
Short-to-Medium Range Air and Missile Defense Composite Battery (assigned to 12 most valuable Regular Airfields)	15	$15.63B
Total		**$35.47B**

$19.84B in Military Construction and Procurement for infrastructure, fuel storage and distribution, reconstitution, and other passive defenses

$15.63B in Procurement for active defenses defenses

Source: Authors.

Note: For additional information on options to enhance airfield resilience, see Walton and Patt, *Flipping the Script*, 77–82.

tential Air Force investments over the next decade to improve surface infrastructure at 20 key regular tanker operation airfields and 20 dispersal airfields, costed at a conservative 1.87 Area Cost Factor.[103] Funding could come from a portion of the sustained increase in military construction (for example, allocating approximately 60 percent of the increase could pay for the necessary projects in five years, 30 percent in 10 years) and/or other sources and additional funding.

Some of the necessary improvements will be outside the Air Force budget. In particular, the Department of the Air Force should "vociferously articulate the need for [DLA Energy] to rapidly field necessary maritime fuel distribution capacity" through measures such as increasing domestic preference cargo, partnering with allies, and increasing working capital fund rates, as well as DLA Energy (informed by service and combatant command guidance) shifting to make its bulk fuel stores resilient.[104] Absent these changes, it is reasonable to expect that regardless of the tanker fleet's capabilities in the air, the PRC could potentially defeat it, and in turn the joint force, on the ground.

Mission System Improvements

Another area for necessary improvement is again not in new tanker aircraft but in mission systems for them. Prioritizing necessary C3, self-defense, fuel transfer, and automation and autonomy improvements would achieve three objectives: address glaring gaps in tanker survivability, adopt an adaptive approach to aerial refueling operations, and mature systems that unlock capabilities for the next generation of tanker aircraft.

The Air Force has committed to enhancing KC-135 and KC-46A connectivity, spending approximately $1.1 billion over the next five years.[105] It will need to make additional outlays to field command and control and mission planning tools inside cockpits and at higher echelons, such as those being developed under the Air Refueling Battle Management initiatives. As tankers gain improved connectivity and as the Air Force fields new self-defense systems, these decision-making tools will be vital to improve the integration between tankers and other units, to improve local decision-making with and without higher-level connectivity, and to allow the Air Force to shift to more dynamic, heterarchical ap-

Table 7.2. Representative Tanker Mission System Improvements

TYPE OF SYSTEM	RDTE AND PROCUREMENT COST (BILLIONS OF FY 2027 DOLLARS)
Command and control and mission planning tools	$1B
Onboard Active Self-Defense Systems on 260 KC-46A	$8B
Survivability Systems	$1B
New Fuel Transfer Systems and Fuel Transfer Automation and Autonomy	$1B
Other Investments	$2B
Total	**$13B**

Source: Authors.

proaches to aerial refueling planning and employment that push capacity forward and organize operations at the edge.

In addition to C3 improvements, the Air Force will need to integrate organic self-defense systems onto the KC-46A fleet and portions of the KC-135 fleet. The LASS program is developing aircraft-agnostic onboard sensing and kinetic/non-kinetic defensive effects. Additional RDTE and procurement funding will be required to incorporate these systems onto a selection of tankers, such as 260 KC-46A. Other survivability enhancements, such as new bailout doors and emergency parachutes, could also improve crew survivability if tankers are destroyed. The Advanced Tanker Systems program could also pursue offboard systems relevant to the tanker fleet, such as long-endurance airborne or surface-launched decoys reproducing tanker signatures.

The development of new fuel transfer systems, such as under the SHARK program, could allow the conversion of commercial aircraft into a latent tanker reserve. Moreover, a common software and hardware abstraction layer could allow boom autonomy developed for one tanker to transfer readily to another, including to future tanker designs.

Lastly, other improvements in automation and autonomy through the CRONUS and other programs could reduce workloads on current tankers and enable autonomous or lightly crewed flights on current and future tankers.[106] Table 7.2 shows initiatives the Air Force could pursue to improve tanker mission systems on current tankers and mature systems that unlock capabilities for the next generation of tanker aircraft.

Fielding New Aircraft

The Air Force requires new tankers. The over-60-year-old age of the KC-135s increases the risk of fleetwide groundings or other catastrophic failures, and the fleet needs to be replaced. The addition of 75 more KC-46As can help with that transition, and the KC-46A has many outstanding features, including its cargo door and cargo capacity. However, the Air Force also requires different tankers.

Our analysis found that the medium-range KC-46A is not well suited for long-range refueling in a large-scale, sustained conflict with the PRC in the vast Indo-Pacific—even when force-extending. Neither is the A330 MRTT+ nor designs that rely on shuttle tanking. Instead, the Air Force requires a medium-sized, long-range, high-offload tanker capable of flying a modest distance into contested air environments. A Medium BWB design could have these attributes and could enable far more dynamic, lethal, and resilient joint force operations.

Such a tanker could provide far more capability and capacity for the same budget or cost considerably less. Table 7.3 shows that assuming a fixed budget of $79.5 billion, the estimated RDTE and procurement cost to buy 250 more improved KC-46As, the Air Force can pursue alternatives. Assuming conservative RDTE, cost per pound, and mission system costs, the Air Force could buy 40 more Medium BWB tankers with a longer range, higher offload, and lower cost than the KC-46A, albeit with limited or no cargo, aeromedical, or passenger capacity. If the Medium BWB RDTE bill were twice as high as estimated, the Air Force could still buy 12 more Medium BWBs. And in a worst-case scenario, if the Medium BWB ended up costing $14 billion in RDTE and the same $310 million APUC as the improved KC-46A (despite being smaller and weighing 24 percent less), then the Air Force could buy 211 Medium BWBs, which would provide 1.7 times as much offload capacity at 2,500 nmi as 250 KC-46As (and 3.1 times as much capacity at 4,500 nmi). Other options are also fiscally viable, such as buying 227 Medium Reduced Signature tankers or 921 CTA.

However, total RDTE and procurement cost and fleet-size comparisons can be misleading since they do not account for the year-by-year budgetary challenges involved in creating new plans or O&S costs. As a result, we generated five representative year-by-year plans that did account for and compare RDTE, procurement, and O&S costs over 30 years and performance metrics. They are summarized below, with costs listed in FY 2027 dollars, and depicted in figure 7.1.

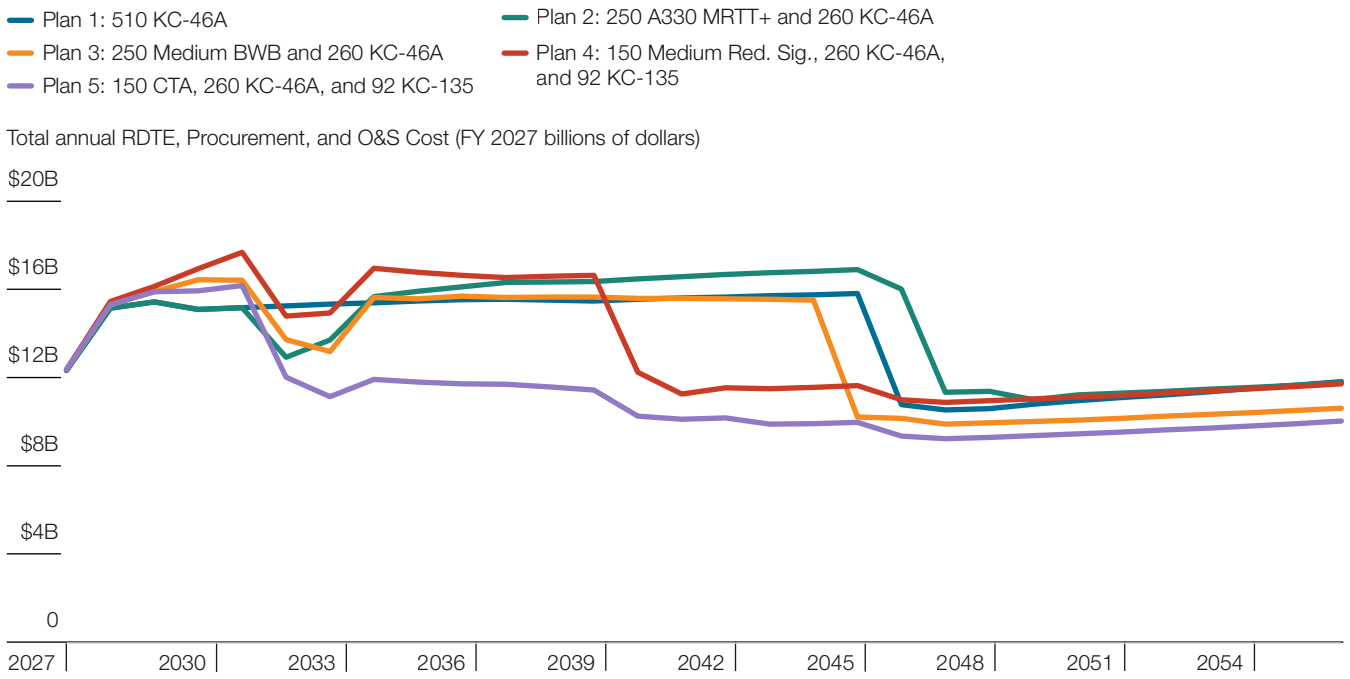
Table 7.3. Comparing Alternatives to Procuring More KC-46As

COSTS IN FY 2027 DOLLARS	KC-46A	A330 MRTT+	MEDIUM BWB	MEDIUM REDUCED SIGNATURE	CTA
Budget (billions)	$79.5B	$79.5B	$79.5B	$79.5B	$79.5B
RDTE (billions)	$2B	$2B	$7B	$12.5B	$5.75B
Remaining budget after RDTE (billions)	$77.5B	$77.5B	$72.5B	$67.0B	$73.75B
Empty weight (lb)	206,000lbs	285,500lbs	155,000lbs	100,000lbs	50,000lbs
Cost per pound	$1,505	$1,103	$1,613	$2,950	$1,600
Average Procurement Unit Cost (millions)	$310M	$315M	$250M	$295M	$80M
Number of tankers can procure	**250**	**246**	**290**	**227**	**921**

Source: Authors.

- **Plan 1: 510 KC-46As.** This plan continues the KC-46A Tanker Production Extension at a rate of 18 per year until the fleet has 510 tankers, slightly more than the 502-tanker requirement, to account for operational attrition. It spends an additional $2 billion in RDTE between FYs 2029 and 2038 to integrate improved self-defense systems that allow new KC-46As to fly 100 nmi closer to threats. It retires KC-135s from the fleet by 2048, and this and all other plans spend a sustaining level of $25 million per year in RDTE per tanker type. Total cost: $413.2 billion.
- **Plan 2: 250 A330 MRTT+ and 260 KC-46As.** This plan also spends $2 billion on RDTE and begins A330 MRTT+ procurement in FY 2032, ramping up to a rate of 18 per year. It retires the last KC-135s in 2050. Total cost: $426.8 billion, which is $13.7 billion more than Plan 1.
- **Plan 3: 250 Medium BWB and 260 KC-46As.** Beginning in FY 2027, this plan spends an additional $7 billion on Medium BWB RDTE and begins their procurement in FY 2032. Procurement gradually increases in rate to 21 per year, which is three higher than for the KC-46A or A330 MRTT+ due to its lower cost. This enables retirement of the last KC-135s slightly earlier by 2046. Total cost: $397.6 billion, which is $15.5 billion less than Plan 1.
- **Plan 4: 150 Medium Reduced Signature, 260 KC-46As, and 92 KC-135R/Ts.** This plan starts Medium Reduced Signature RDTE in FY 2027, spending a total of $12.5 billion. It procures 150 Medium Reduced Signature tankers, starting in FY 2032, at an escalating rate that reaches 21 per year. Given the design's role as a child tanker, 150 is

Figure 7.1. Cost of Plans by Year



Source: Authors.

an appropriate fleet size to generate coverage for a modest number of ARCPs in contested or highly contested air environments. Because the plan completes KC-46A procurement at 75 more and does not procure another medium- or long-range tanker, it spends an additional $800 million in RDTE and $50 million per aircraft to further extend the life of 92 KC-135s. Total cost: $401.8 billion, which is $11.3 billion less than Plan 1.

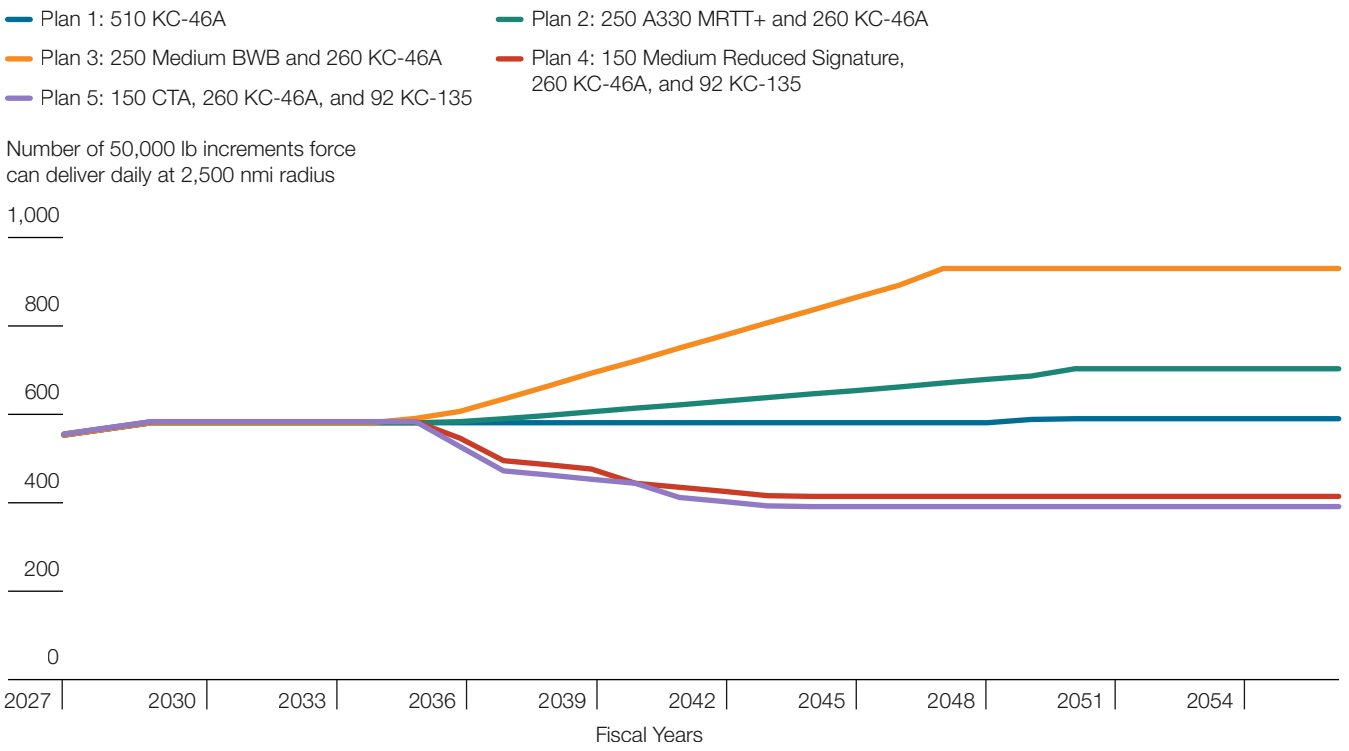
- **Plan 5: 150 CTA, 260 KC-46As, and 92 KC-135R/Ts.** This plan follows the same procurement profile as the preceding one, with the difference that CTA RDTE costs $5.75 billion. Total cost: $334.9 billion, which is $78.3 billion less than Plan 1.

Many variations of these plans could be created, but the current ones serve to explore choices available to and constraints impacting the Air Force. Plans 3–5 cost $11.3 to $78.3 billion less than Plan 1, which simply procures more KC-46As. Although introducing new developmental designs costs a billion or so more per year toward the end of the 2020s and early 2030s in RDTE costs, in the case of Plans 3 and 5, by 2032 the total costs dip below or roughly match the total annual cost of Plan 1's continued procurement of KC-46A.

The cost differences are in part driven by RDTE and new aircraft procurement decisions, but on average 79 percent of the plans' total life cycle costs are for O&S. Consequently, designs that reduce those costs and fleet plans that retire the KC-135 sooner (and thus avoid continued major growth in support and service life extension costs) could generate billions of dollars in savings.

One example is the Medium BWB, which we conservatively estimate could reduce per-aircraft average unit O&S costs

Figure 7.2. Fuel Offload Capacity of Plans by Year



Source: Authors.

by 11 percent over 30 years relative to the KC-46A. These savings are chiefly driven by lower operations costs due to reduced fuel consumption, as well as slightly lower maintenance costs resulting from the aircraft's fewer mission roles and relatively smaller size. Toward the end of the plans' 30-year spans, Plan 3's procurement of Medium BWBs leads to more than $1 billion per year in O&S cost savings compared to Plan 1, which only procures KC-46As. This finding is relatively robust to changes in the Medium BWB O&S cost assumption: its O&S costs could be about 21 percent higher than modeled before Plan 3's 30-year lifecycle cost exceeds that of the all-KC-46A Plan 1. The cost advantage is also relatively robust to acquisition-cost growth. Holding O&S and other fleet costs constant, Medium BWB procurement costs could increase by approximately 25 percent, from $250 million to about $312 million per aircraft. Or modeled Medium BWB RDTE costs could more than triple before Plan 3's 30-year lifecycle cost exceeds that of a plan that only bought KC-46A.

Lastly, despite the differences, the plans demonstrate how difficult it will be to rapidly retire the KC-135 fleet unless the tanker portfolio receives a windfall of investment: The KC-135 will likely be present in the Air Force until the late 2040s, if not longer.

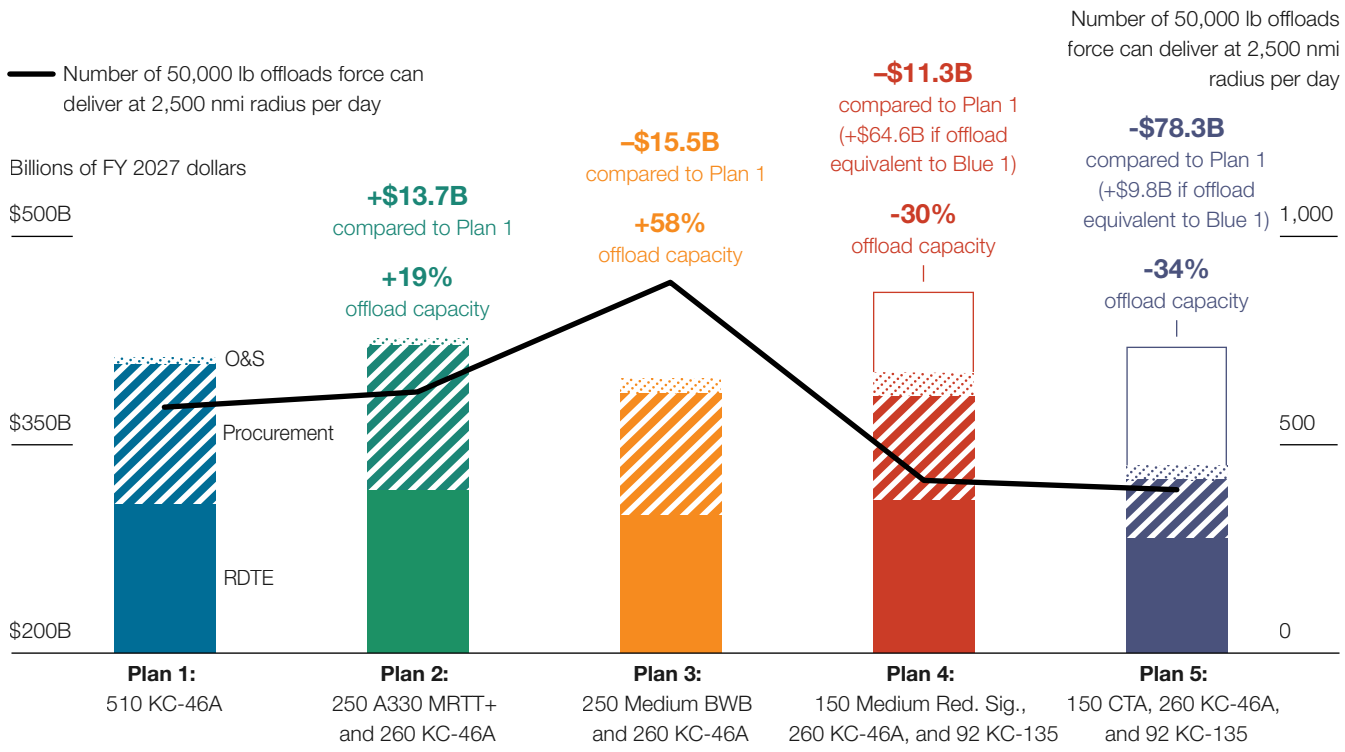
The plans also exhibited major differences in fleet refueling capacity. Plan 3, which fields a mixed KC-46A and Medium BWB

fleet, greatly outperforms the alternatives at all ranges and offload amounts. Figure 7.2 shows the ability to deliver 50,000 lb increments of fuel (enough to refuel four fighters or one medium-sized aircraft once) at a mission radius of 2,500 nmi, which is approximately the weighted average distance where ARCPs might need to take place to maintain 1 percent or less daily attrition on the ground. The figure incorporates direct delivery, force extension, shuttle tanking, and force-extended shuttle tanking mission profiles as appropriate, as well as mission capable and operational availability rates.

At 2,500 nmi, Plan 3's fleet of KC-46A and Medium BWB tankers could deliver approximately 1.6 times as much fuel as Plan 1, which added KC-46As, and 2.2–2.4 times as much fuel as Plans 4 and 5, which added Medium Reduced Signature and CTA designs. At longer ranges and higher offloads, the difference was even more stark. For example, at 4,500 nmi radii and 100,000 lb offloads, Plan 3 could deliver approximately three times as many increments of fuel as Plan 1. This massive increase in the ability to refuel receiver aircraft at range compared to today's force would ensure ample availability of aerial refueling and enable supported forces to fight and maneuver with far greater dynamism, tempo, flexibility, and ultimately lethality.

To match Plan 3's offload capacity with a KC-46A-only force would require 805 KC-46A—303 more tankers than the current 502 tanker requirement—would require tripling KC-46A

Figure 7.3. Costs Over 30 Years and Offload Capacity Provided by Plans, Compared to Plan 1 That Fields All-KC-46A Force



Source: Authors.

Impact of Readiness and Airlift on Aerial Refueling Plans

The Air Force will need to evaluate other factors that could impact its aerial refueling plans. One is the readiness of its current fleet, which has been extremely active in Operation Epic Fury and other contemporary operations. The Air Force should work with the Office of the Secretary of War to meter demand where possible to allow aircraft and aircrews to reset. It should also increase readiness funding, particularly to create an appropriate reserve of Weapons Systems Sustainment parts.[107]

Another factor is the future of airlift. Plan 3's force of 260 KC-46As and 250 Medium BWBs would provide 14 percent more secondary airlift capacity (measured in 463L pallet positions) than the Air Force's 2026 fleet of 373 KC-135s and 103 KC-46As. This is because each KC-46A can accommodate up to three times as many 463L pallet positions as a KC-135. Accordingly, even though the Medium BWB is modeled as a dedicated tanker without cargo, passenger, or aeromedical capacity, the planned introduction of 260 KC-46As that replace KC-135s substantially increases the palletized cargo capacity of the tanker fleet. This secondary mobility capacity would provide commanders with additional flexibility and could help husband the life of the C-5M and C-17A fleets.

An all-KC-46A force would provide substantially more secondary mobility capacity than Plan 3. However, dedicated secondary mobility missions have historically represented only a small share of KC-135 employment. For example, KC-135s at Royal Air Force station Mildenhall carried passengers or cargo on less than 4 percent of their annual missions in a typical year, while a KC-135 operator supporting operations in Southwest Asia characterized approximately 99 percent of deployed missions as aerial refueling.[108] These secondary missions nevertheless provide useful operational flexibility, particularly because cargo, passengers, or aeromedical patients can sometimes be carried in conjunction with aerial refueling missions.

The demand for mobility fleet modernization could also complement or compete with aerial refueling modernization. For example, if the C-17A were reengined, its propulsion modernization could create opportunities for engine commonality with new mobility aircraft such as a Medium BWB tanker or Next-Generation Airlift aircraft, although the requirements of each design could favor different engines. At the same time, RDTE and procurement funding for next-generation refueling and airlift aircraft could compete for limited mobility investment.

Cognizant of the major challenges facing the airlift fleet—especially the C-5M force—we contend that the Air Force's next mobility aircraft should be a tanker. The aging KC-135 requires replacement more urgently than the C-5M or C-17A, and current gaps in aerial refueling capability and capacity could more severely affect priority campaign outcomes than limitations in the cargo mobility fleet. Moreover, in our modeling, longer-range, higher-offload tankers such as the Medium BWB generally improved the force's ability to rapidly deploy forces and supplies more than new, longer-range cargo aircraft. This is because the Medium BWB could support the rapid deployment of combat aircraft, such as bombers and fighters, as well as mobility aircraft, whereas a longer-range cargo aircraft primarily improves the movement of cargo and passengers. Although this insight merits further analysis, particularly in light of the fractionating options for cargo mobility (from C-130, C-17A, and C-5M to a broader range of inter- and intra-theater designs), it affirms the importance of prioritizing development of a tanker as the Air Force's next mobility aircraft.

procurement to 45 tankers per year, would result in a force that costs $8 billion more in annual O&S costs, and would cost $198.5 billion more than Plan 3 over the next 30 years. The procurement and O&S costs to field and personnel requirements to crew such a force are currently impractical given other Air Force demands. The Air Force can pursue improved alternative designs that provide more capacity at lower cost.

Notably, Plans 4 and 5 had a total of 510 tankers, as the other plans did, but introducing shuttle tanking Medium Reduced Signature and CTA tankers lowered total offload capacity to on average 28 percent less than that of today's force. Although under these plans the Air Force would trade capacity for improved refueling capability in contested or highly contested air environments, the major drop in potential capacity should give planners pause. If Congress mandated a 7 percent increase in the tanker fleet's size and capacity to address significant gaps, a 28 percent drop in capacity would likely force dramatic changes in operational plans and employment concepts. In turn, these changes would likely hinder the ability to simultaneously maintain strategic deterrence, defend the homeland, and project power. The drop in capacity underscores how shuttle tanking options serve as range extenders for parent tankers in specific scenarios but do not recapitalize the KC-135 fleet.

If instead the Air Force wanted to retain current capacity and the flexibility to address a range of scenarios around the world while fielding shuttle tanking designs, it would likely need to significantly increase the size of its tanker fleet. To achieve capacity equivalent to Plan 1, Plans 4 and 5 would need to either retain approximately 300 KC-135s well past the century mark or procure 265–285 more KC-46As beyond the 75 KC-46A Tanker Production Extension aircraft. The latter approach would make revised Plans 4 and 5 cost $10 billion and $65 billion more, respectively, than Plan 1 over 30 years, and $25 billion and $80 billion more than Plan 3. The resulting force structures of 675 or 695 tankers would also be difficult and expensive to crew and operate. Figure 7.3 summarizes the costs and offload capacities provided by the different plans.

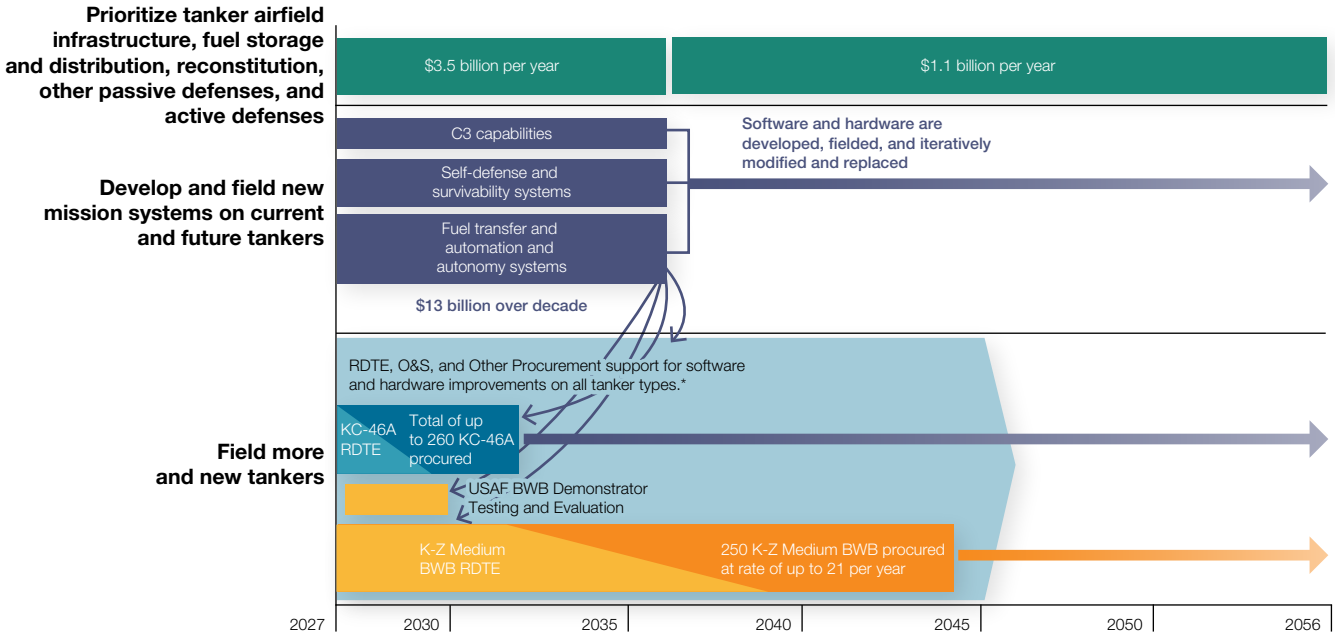
Our analysis concludes that a medium-sized, long-range, high-offload tanker such as the Medium BWB is the most promising next tanker aircraft for the Air Force to field. It provides far more refueling capacity, capability, optionality, and resilience than alternatives; it could fly a modest distance closer to threats; and it could cost considerably less. Multiple companies could develop and field a Medium BWB.

Proposed plan

To field an effective and resilient aerial refueling architecture, the Air Force can take a holistic approach that appropriately funds elements of the entire aerial refueling architecture. As shown in figure 7.4, we propose that starting in FY 2027, the Air Force and other parts of the DoW should prioritize military construction and other funding to enhance the capacity and resilience of its most important tanker airfields. The Air Force should also continue and increase funding for C3, self-defense, fuel transfer, and automation and autonomy mission systems for current and future tankers. These should be integrated by an adaptive and extensible software ecosystem.

In terms of aircraft, the Air Force should resolve ongoing deficiencies with the KC-46A, acquire a requisite number of KC-46A Tanker Production Extension aircraft, and direct FY 2027 funding to mature medium-sized, long-range, high-offload capacity tanker designs, such as Medium BWB. Then, assuming successful evaluation of its BWB demonstrator in 2027 and 2028, it should award in FY 2028 a development contract for a Medium BWB tanker. This approach would allow the testing of prototype aircraft before procurement awards starting in FY 2032 and rising to a rate of 21 per year, which is three more than currently planned for Tanker Production Extension KC-46As. If deemed necessary to hedge against maturity and schedule risk with its new tanker, the Air Force could be prepared to exercise the option to extend the procurement of KC-46A Tanker Production

Figure 7.4. Summary of Proposed Aerial Refueling Architecture



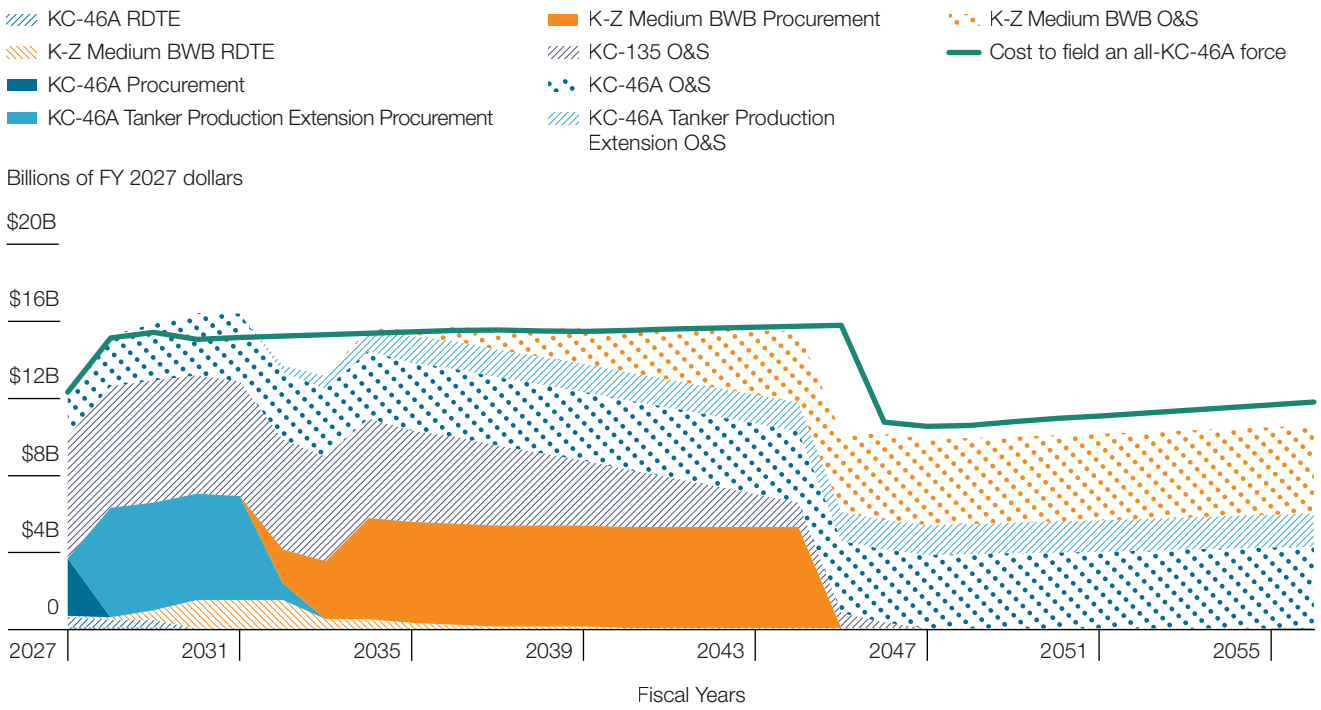
Source: Authors.

Extension aircraft (at either the same rate or a reduced rate) for another year or more.

If 75 KC-46A Tanker Production Extension aircraft were procured, the resulting mixed fleet of 260 medium-range refueling-, cargo-, passenger-, and aeromedical-capable KC-46As and 250 long-range, high-offload dedicated refueling Medium BWBs would complement each other and improve the Air Force's ability to succeed in its most stressing scenarios, as well as sustainably execute other operations across the world. The proposed plan's yearly tanker costs (shown in figure 7.5) would require additional RDTE outlays in the late 2020s and early 2030s. But its total RDTE, procurement, and O&S costs over 30 years would amount to $15.5 billion less than a plan that solely procured KC-46A, and the resulting fleet could deliver 1.6–2.8 times as many increments of fuel.

Other variations on this plan are possible and may be desirable. For example, if budgetary limits constrained funding available for concurrent RDTE and procurement, the Air Force could reduce its KC-46A Tanker Production Extension buy to 49 vice 75 aircraft. The resulting fleet of 234 KC-46A (and 250 or more Medium BWB) would provide at least 63 percent more aerial refueling capacity and an equivalent level of cargo capacity as today's tanker fleet. It would also allow approximately $7.8 billion to be redirected toward Medium BWB RDTE and procurement as well as other force demands such as surface infrastructure and mission system modernization. Similarly, if the Air Force found that it required a small fleet of reduced signature shuttle tankers, it could use savings from a slimmed KC-46A Tanker Production Extension buy (or foregoing it entirely) and redirect the funds to that program, in addition to the Medium BWB. Investments in a shuttle tanker should, however, be weighed against alterna-

Figure 7.5. Proposed Plan Aircraft Costs



Source: Authors.

tive investments in longer-range weapons and combat aircraft organic range, and a medium-sized, long-range, high-offload tanker such as a Medium BWB should be the Air Force's next and top mobility priority.



8. RECOMMENDATIONS, COUNTERARGUMENTS, AND CONCLUSION

For decades, the combination of a global network of forward airfields (predominantly on allied and partner territory) and mostly medium-range tankers has enabled the United States to promptly project power abroad.[109] But those circumstances have changed. Airfields—especially forward and intermediate ones—are vulnerable to large-scale attack, and medium-range tankers lack the range to effectively sustain operations from more distant ones or the survivability in the air to reach desired operating locations.

In response, the aerial refueling architecture should transform, boosting the resilience of its surface infrastructure, incorporating an adaptive ecosystem of mission systems that can raise force effectiveness and survivability and unlock options for future tanker designs, and fielding a new type of tanker. Medium-sized, long-range, high-offload tankers such as Medium BWBs that could fly a modest distance closer to threats could create an abundance of aerial refueling that unlocks new standoff and penetrating concepts of operation, enables more dynamic, lethal, and resilient operations, and could help deter conflict or win if necessary.

Thankfully, the actions necessary to transform the US aerial refueling architecture are viable in terms of technological, industrial, and fiscal capability and capacity. The Air Force will need to conduct its own analyses of this mission area and how it aligns with broader force design and force structure trends; however, to pursue this improved approach, we recommend the following:

1. The Air Force should prioritize the necessary surface infrastructure capacity and resilience, including through pas-

Photo: A specially painted KC-135 Stratotanker sits on the flight line at Rickenbacker Air National Guard Base in Columbus, Ohio, on December 4, 2025. (US Air Force)

sive and active defenses, to sustain large-scale tanker operations from key well-defended intermediate and distant tanker bases, or strongpoints. It should also foster access at other locations, including large commercial airfields, and nurture its invaluable relationships with NATO and other allies that provide access to tanker airfields.

2. The Air Force should prioritize necessary C3, self-defense, fuel transfer, and automation and autonomy improvements to address glaring gaps in tanker survivability and improve performance. It should adopt an adaptive approach to aerial refueling operations and capabilities and mature mission systems on existing tankers, test aircraft, and its BWB demonstrator that unlock capabilities for the next generation of tanker aircraft and could provide an ability to convert commercial aircraft into tankers. Much like the Next Generation Air Dominance team of systems, at the heart of this approach is a common software ecosystem and open architecture that enables investments to be extended across aircraft types and capabilities to be integrated across the mobility enterprise, the broader Air Force, the joint force, and allies and partners.
3. Future tanker assessments should account for:
    - Realistic airfield infrastructure characteristics, especially fuel stores, ramp space, pavement firmness, and runway lengths
    - Threats to airfields (and aircraft and personnel at them), bulk fuel sourcing, storage, and distribution, and other supporting systems
    - Access and overflight restrictions
    - Threats to tankers in the air
    - Aircraft performance at various fuel loads[110]
    - The ability to support desired missions and theater- and campaign-level performance at scale, accounting for operational availability, under contestation, over protracted periods, from relevant airfields, and under different airfield conditions
4. The Air Force should develop and procure 250 medium-sized, long-range, high-offload tankers capable of standing in a moderate distance from threats. A tanker with such attributes, such as a Medium BWB, could provide far more capacity, capability, optionality, and resilience than alternatives, and is essential for the Air Force and broader joint force to fight effectively. The Air Force could field it by the mid-2030s for reasonable RDTE and procurement costs that align with projected budgets, and it could cost considerably less than simply buying more KC-46As.

The proposed set of recommendations can enable the Air Force and DoW to field an effective and resilient aerial refueling architecture that addresses the needs of the nation. Implementing them, though, will require aligning an interdependent set of investments across different areas and prioritizing within portfolios. Air Force, DoW, and congressional leaders may also face some of the following counterarguments.

1. **If airfields are vulnerable, forego spending more on surface infrastructure and simply disperse.** Encountering severe threats to airfields, one reaction may be to avoid attempting to make airfield operations more resilient and instead depend on greater tanker distribution among airfields and dispersion at airfields. However, aerial refueling aircraft depend on operating from airfields with copious amounts of fuel, which ties tanker operations to a smaller set of airfield targets. And as witnessed at Prince Sultan Air Base, dispersion alone is not enough to avoid attack in an era of persistent surveillance and precision targeting. Therefore, unless major improvements to the aerial refueling architecture are made, tanker operations from intermediate and distant airfields (to include in the contiguous United States) are at risk of being suppressed by enemy attack. In response, DoW should not only pursue access to more potential operating locations, but also generate more resilience at key forward, intermediate, and distant airfields. Due to fiscal constraints, the Air Force will need to be judi-

cious regarding how and where it funds surface architecture improvements, prioritizing well-defended intermediate and distant tanker bases, or strongpoints.

2. **Skip improving current tankers and accelerate next-generation tankers.** To husband RDTE funding for next-generation tankers, the Air Force could choose to skip mission system improvements on current tankers. However, not modernizing mission systems on existing tankers and demonstrator aircraft would continue grave operational risks faced by the bulk of the force and pass development risk to future tanker types. Given fiscal constraints, though, the Air Force should be selective regarding the types of mission system improvements it incorporates on tankers, such as by preferencing the incorporation of more new mission systems on KC-46A and special mission KC-135 tankers.

3. **Longer-range aircraft and weapons obviate the need for a new, longer-range tanker.** US Air Force and Navy initiatives that extend the organic and weapons range of aircraft should be pursued, since they can increase the lethality and survivability of the force and reduce the reliance of aircraft on aerial refueling—especially in more-contested airspace. However, current and emerging service and joint concepts emphasize greater distribution, dynamism, and tempo—all of which require greater reach and endurance provided by aerial refueling support to enhance force lethality and survivability. Moreover, many of the improvements in aircraft organic range are being offset by other measures (e.g., B-52J engine upgrade range extension may be counteracted by the additional drag imposed by large, external weapons carriage). Lastly, our analysis indicates that whether the Air Force and Navy adjust their force structures to emphasize shorter-range fighters or long-range strike assets, more and more-effective aerial refueling capacity is needed. Even if the Air Force shifted to a force structure that almost exclusively favored long-range Pulsed Force bombers and mobility aircraft with palletized munitions, that force would require long-range, high-offload aerial refueling aircraft (such as the examined Medium BWB). This is because—even when force extending—medium-range KC-135 and KC-46A tankers could only support a very small number of large offloads when operating from laydowns that kept their attrition on the ground to manageable levels, which would greatly limit the capacity and maneuver of these Pulsed Forces. Regardless of changes in force structure and concepts, the Air Force requires a new, longer-range tanker to generate necessary lethality.

4. **Delay a future tanker program.** Given competing priorities, the Air Force could consider delaying the development and fielding of a future tanker. However, it is well past time to replace the 1950s-era KC-135 fleet given the structural and reliability concerns it faces. Further delays would compel the Air Force to incur more, increasingly severe operational risk and force it to continue buying range-limited KC-46As to avoid a break in the delivery of new aircraft or fund another, more expensive KC-135 service life extension to prolong their operation past the century mark. A new tanker program is urgently needed to recapitalize the geriatric KC-135 fleet and to field a long-range, high-offload tanker capable of standing-into contested airspace.

5. **BWBs are ineffective or inefficient tankers.** Medium BWBs are a promising class of design that provide necessary attributes for the Air Force's future tanker. The performance of BWBs and other types of designs should be evaluated. However, as a new type of design, there are questions regarding how BWB would perform as tankers. One concern is that the aerodynamic wake of BWB aircraft may make it more difficult for receiver aircraft to mate with a BWB tanker. However, published analyses generally indicate that BWB and transport flying-wing aircraft can produce lower-intensity trailing-vortex wakes than conventional tube-and-wing aircraft of comparable capacity.[111] Additional studies on specific design configurations and experiments using the Air Force's BWB demonstrator can shed further light on this topic, but in general it appears that BWB tankers should produce a smoother ride for receivers.

Another concern is that a Medium BWB equipped with moderate-bypass-ratio engines could incur a propulsion-efficiency disadvantage relative to tube-and-wing aircraft equipped with newer, higher-bypass-ratio engines, including at the 20,000–30,000-ft altitudes commonly used to refuel most aircraft.[112] Although efficiency will ultimately depend on the specific tanker and engine designs, BWB aircraft generally exhibit substantially greater aerodynamic efficiency than comparable tube-and-wing configurations.[113] This aerodynamic advantage should tend to reduce mission fuel consumption despite potential propulsion-efficiency disadvantages. Moreover, because BWB designs can efficiently cruise at higher altitudes, the relative benefits of the configuration tend to increase on longer-range missions. In peacetime and on many short-range, long-endurance missions, tankers may spend much of a sortie operating at lower aerial-refueling altitudes. On medium- and long-range missions, however, roughly 75–95 percent of flight time may be spent in high-altitude cruise. Future tanker designs should therefore provide improved fuel efficiency at lower altitudes while maximizing efficiency during high-altitude cruise.

6. **Simply buy more KC-46A.** Given competing priorities, the temptation to continue buying more incumbent KC-46A will be strong. With the Air Force planning on fielding at least 185 KC-46A and possibly up to 260 (more than half of its 502-tanker requirement) or more, it may consider filling out the rest of its force with KC-46A outfitted with improved mission systems, thus achieving fleetwide economies and avoiding the budgetary and schedule risks associated with a new development program. It should resist doing so. A tanker fleet of KC-46As alone is insufficient to win in conflicts that require long-range, contested refueling operations.[114] Instead, the Air Force can pursue alternative plans that provide far more capability and capacity at a lower cost and fit within projected resource constraints.

Aerial refueling is essential to US military operations and is in high demand across the world. But too often it is also the limiting factor on the distribution, pace, and lethality of US campaigns. Worse still, as the KC-135 fleet continues to age and as adversaries field ways to neutralize US aerial refueling on the ramp and in the air, this strategic advantage is increasingly a liability that could cause the United States to lose a war—especially against the PRC in the Indo-Pacific.

The Air Force and DoW have an opportunity, though, to transform. By prioritizing across portfolios, it can, within planned budget levels, boost the resilience of its surface architecture, incorporate an adaptive ecosystem of mission systems that can raise force effectiveness and survivability and unlock options for future tanker designs, and field a new type of tanker. Medium-sized, long-range, high-offload tankers such as Medium BWB that could fly a modest distance closer to threats would not only cost less than buying more KC-46A, but more importantly could create an abundance of aerial refueling that unlocks new standoff and penetrating concepts of operation, enables more dynamic and lethal operations, and sustains the global reach of US forces, regardless of enemy attack. Collectively, this force architecture would provide far greater capacity and capability to address a range of demands, including the United States' most challenging scenarios against the PRC, and unleash the full potential of the joint force to deter conflict or win if necessary.

ABBREVIATIONS

APUC: average procurement unit cost

ARCP: air refueling control point

bbl : barrel

BWB: blended wing body

C3: command, control, and communications

C5ISRT: command, control, communications, computers, cyber, intelligence, surveillance, reconnaissance, and targeting

CAP: combat air patrol

CFL: Critical Field Length

CRONUS: Combat Refueling and Operations Networked Universal System

CTA: collaborative tanker aircraft

DFSP: Defense Fuel Support Point

DLA: Defense Logistics Agency

DoD: US Department of Defense

DoW: US Department of War

FY: fiscal year

HA/DR: humanitarian assistance and disaster relief

LASS: Large Aircraft Survivability Systems

MRTT: Multi-Role Tanker Transport

NATO: North Atlantic Treaty Organization

NGAD: Next Generation Air Dominance

NGAS: Next Generation Air Refueling System

O&S: operations and support

PAUC: program average unit cost

PLA: People's Liberation Army

PRC: People's Republic of China

RDTE: research, development, test, and evaluation

SHARK: Small Hybrid Aerial Refueling Kit

TPFDD: Time-Phased Force and Deployment Data

USTRANSCOM: US Transportation Command

ENDNOTES

1 Timothy A. Walton and Bryan Clark, *Resilient Aerial Refueling: Safeguarding the US Military's Global Reach* (Hudson Institute, 2021), https://www.hudson.org/national-security-defense/resilient-aerial-refueling-safeguarding-the-us-military-s-global-reach; Timothy A. Walton and Dan Patt, *Flipping the Script: Redesigning the US Air Force for Decisive Advantage* (Hudson Institute, 2026), https://www.hudson.org/national-security-defense/flipping-script-redesigning-us-air-force-edge-pulsed-resilient-airfields-timothy-walton-dan-patt; and Timothy A. Walton, Shane Dennin, and Sean Maxfield, *Indo-Pacific Infrastructure and Logistics* (working title; Hudson Institute, forthcoming 2026).

2 DefenceGeek (@DefenceGeek), "US Tanker Fleet Update - 13/08/2026", X, August 13, 2026, https://x.com/DefenceGeek/status/2087826127016378416.

3 Diana Maurer, *Aerial Refueling Tankers: Air Force Needs More Focused Metrics and a Risk-Based Mitigation Plan to Improve Sustainment* (US Government Accountability Office, June 2026), https://www.gao.gov/assets/gao-26-109154.pdf.

4 This Red Attack Simulation is a Monte Carlo simulation with 100,000 trials. It takes a predetermined set of airfields that Red will attack over the course of seven days. Red has a fixed number of aircraft, missile launchers, and munitions. The simulation accounts for launch platforms and munitions performance and inventory, as well as airfield ramp space and distance from the PRC. At the beginning of each trial, a "strike list" is probabilistically made per range band, choosing which airfields to attack first. Munitions assigned to a band are assigned to attack that airfield until it is destroyed, upon which Red will move to attack the next airfield. This models how the PLA may organize overwhelming strikes rather than a random spread of strikes without focused suppression, leaving airfields damaged but still operational. There is an attack ceiling per band based on assumptions of PLA munitions stockpile usage, and there are assumptions made regarding the impact of Blue defenses on Red strike threats. Each airfield is assigned a number of strikes necessary to suppress it. When the threshold is reached, the airfield is considered suppressed. The presented video screenshot from the generated simulation shows the average of 100,000 trials and does not represent one trial. It is best understood as a risk assessment for airfields overall. One trial would feature complete suppression of some airfields, while leaving others completely operational, and a few partially damaged.

5 Of note, only five KC-135RTs are receiver-equipped and capable of receiving fuel.

6 Walton and Clark, *Resilient Aerial Refueling*, 13.

7 Walton and Clark, *Resilient Aerial Refueling*, 9.

8 Jan Tegler, "Lack of Connectivity Possible Contributor to Middle East KC-135 Mishap," *National Defense Magazine*, April 27, 2026, https://www.nationaldefensemagazine.org/articles/2026/4/27/lack-of-connectivity-possible-contributor-to-middle-east-kc135-mishap.

9 Bryan Clark and Dan Patt, *Building a Team for Next Generation Air Dominance* (Hudson Institute, 2022), https://www.hudson.org/national-security-defense/building-a-team-for-next-generation-air-dominance.

10 Of note, only five KC-135RTs are receiver-equipped and capable of receiving fuel.

11 In *Flipping the Script*, the planned Blue force faced a 20 percent gap in desired aerial refueling support. Within the simulation, to meter demand, only half of the potential sorties that could have used aerial refueling were provided with aerial refueling. Therefore, there was an approximately 40 percent gap in potential receiver refuelings, and only 60 percent of the potential demand was met. (Walton and Patt, *Flipping the Script*, 100.)

12 The image of the Medium BWB is based on the Boeing ERA-009H1 concept in "Figure 8. A three-view drawing of the ERA-0009H1 concept including relevant dimensions" in Jesse R. Quinlan and Frank H. Gern, "Conceptual Design and Structural Optimization of NASA Environmentally Responsible Aviation (ERA) Hybrid Wing Body Aircraft," NASA Langley Research Center, 2016 AIAA Science and Technology Forum and Exposition, January 4, 2016, https://ntrs.nasa.gov/citations/20160007538. The image of the Medium Reduced Signature design is based on Boeing's "stealthy BWB" cited in Joseph Trevithick, "Stealthy Tanker-Transport Aircraft Concept Unveiled by Boeing," *War Zone*, January 26, 2023, https://www.twz.com/stealthy-tanker-transport-aircraft-concept-unveiled-by-boeing.

13 "X-48 Hybrid/Blended Wing Body," National Aeronautics and Space Administration, 2012, https://www.nasa.gov/wp-content/uploads/2021/09/171791main_fs-090-dfrc.pdf.

14 "Entities Identified as Chinese Military Companies Operating in the United States in Accordance with Section 1260H of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (Public Law 116-283, Section 1260H, as Amended)," US Department of Defense, June 8, 2026, 9, https://media.defense.gov/2026/Jun/08/2003945537/-1/-1/1/ENTITIES-IDENTIFIED-AS-CHINESE-MILITARY-COMPANIES-OPERATING-IN-THE-UNITED-STATES-IN-ACCORDANCE-WITH-SECTION-1260H.PDF.

15 This assessment accounts for KC-46A and Medium BWB force extending where appropriate. For example, at 4,500 nmi radii, the KC-46A can on a sustained basis deliver 0.39 50,000 lb and 0.19 100,000 lb offload increments of fuel per day, compared to the Medium BWB delivering 2.09 and 0.97 offload increments, respectively.

16 The following notes correspond with the superscripted numbers in table ES.1.

1. This is the average relative percentage of tankers required in the different mission vignettes examined. For more information, please see Figure 4.10.

2. Total cost accounts for tanker program average unit cost (PAUC) and F-35A fighter average procurement unit cost (APUC). For more information, see figure 4.14.

3. This is the estimated number of airfields from which tankers can sustain a single continuous air refueling control point (ARCP) in the Philippine Sea, while keeping tanker attrition on the ground to ≤1 percent of the committed tanker force of up to 200 tankers per day. For more information, see figure 5.3.

4. This assessment accounts for the days required to deploy the same number of aircraft and cargo loads as the baseline KC-46A force. It assumes PRC (Red) attacks on allied (Blue) airfields begin on Day 8 of the deployment. For more information, see table 5.2.

5. This is the approximate, estimated number of ARCPs that can be sustained in the Philippine Sea over a month at a ≥90 percent probability of success amidst PRC attacks on airfields, while maintaining a tanker laydown that keeps tanker attrition on the ground to ≤1 percent of the committed tanker force of up to 200 tankers per day. For more information, see figure 5.5.

17 As testified by Chief of Staff of the Air Force General Ken Wilsbach, despite some deficiencies, the KC-46A is a "phenomenal aircraft" that "has been doing a great job in Epic Fury and all over the world." See *Hearings to Examine Proposed Budget Estimates and Justification for Fiscal Year 2027 for the Department of the Air Force Before US Senate Committee on Appropriations, Subcommittee on Defense*, 119th Cong. (June 9, 2026), (testimony of Gen. Kenneth S. Wilsbach, chief of staff of the Air Force), 1:23:09, transcript provided by FirstBranch, https://www.firstbranch.ai/hearing/338545.

18 KC-46A procurement cost is based on the FY 2031 Flyaway Unit Cost of $324.159 million ($299.473 million in FY 2027 dollars). We estimate an additional $10 million or more in self-defense capabilities would likely be required for an improved KC-46A. See *Fiscal Year (FY) 2027 Budget Estimates: Air Force Justification Book, Aircraft Procurement*, vol. 1 (US Department of War, April 2026), 89, https://www.af.mil/Portals/1/documents/Secretariat%20of%20the%20AF/SAF-FM/Budget%20-%202027/Budget%20docs/FY27%20Air%20Force%20Aircraft%20Procurement%20Volume%20I.pdf?ver=4kiKWbFkcqsD4dDrO7-P4g%3d%3d.

19 Walton and Patt, *Flipping the Script*, 113–125.

20 This measures the number of 50,000 lb and 100,000 lb increments of fuel that could be delivered per hour by the proposed tanker fleet at a radius of 2,500 nmi and 4,500 nmi, respectively, and compares it to the amount that could be delivered by an all-KC-46A fleet.

21 Cargo capacity is measured in terms of 463L pallet positions. Refueling capacity measures the number of 50,000 lb and 100,000 lb increments of fuel that could be delivered per hour by the proposed tanker fleet at a radius of 2,500 nmi and 4,500 nmi, respectively, and compares it to the amount that could be delivered by an all-KC-46A fleet.

22 Walton and Patt, *Flipping the Script*, 11.

23 Walton and Clark, *Resilient Aerial Refuelin*g; Walton and Patt, *Flipping the Script*.

24 Quinlan and Gern, "Conceptual Design and Structural Optimization of NASA Environmentally Responsible Aviation (ERA) Hybrid Wing Body Aircraft"; Trevithick, "Stealthy Tanker-Transport Aircraft Concept Unveiled by Boeing."

25 Walton and Patt, *Flipping the Script*, 72. For example, given concomitant national demands, during Operation Odyssey Dawn, the 2011 military intervention into the Libyan Civil War, the deployment of 34 US Air Force tanker aircraft meant that "every taskable US Air Force tanker unit was engaged in ongoing operations, training, maintenance, or mandatory rest." See Walton and Clark, *Resilient Aerial Refueling*, 21. For more information on Aaron A. Borszich's concept of taskable tails, see 24–25.

26 DefenceGeek (@DefenceGeek), "UPDATE: US Air Force Tanker Fleet 14/04/2026 (Ceasefire Day 7)," X, April 14, 2026, https://x.com/DefenceGeek/status/2043988387103699019/photo/1.

27 *Hearing on Posture and Readiness of the Mobility Enterprise Before House Armed Services Subcommittees on Seapower and Projection Forces*, 119th Cong. (March 18, 2026), (testimony of Gen. Randall Reed, commander, US Transportation Command), 36:31–37:36, 39:06–39:58, transcript provided by FirstBranch, https://www.firstbranch.ai/hearing/119070; *Hearing on Posture and Readiness of the Mobility Enterprise Before House Armed Services Subcommittees on Seapower and Projection Forces*, 119th Cong. (March 18, 2026), (statement of Gen. Randall Reed, commander, US Transportation Command), 5, 10, https://docs.house.gov/meetings/AS/AS28/20260318/119070/HHRG-119-AS28-20260318-SD004.pdf.

28 Matthew Cox, "How the 2027 Budget Will Change the Air Force Tanker Fleet," *Air and Space Forces Magazine*, April 28, 2026, https://www.airandspaceforces.com/air-force-tanker-fleet-2027-budget/.

29 Walton and Patt, *Flipping the Script*, 72–73.

30 US Air Force, "B-21 Raider Accelerates Delivery of Long-Range Strike Capability," news release, April 14, 2026, https://www.af.mil/News/Article-Display/Article/4459893/b-21-raider-accelerates-delivery-of-long-range-strike-capability/.

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32 A 1982 US Congressional Budget Office study asserted that the use of external cruise missiles on B-52 bombers increased each bomber's average tanker requirements by 34 percent. John J. Hamre and David S. Neill, *Aerial Tanker Force Modernization* (CBO, 1982), https://www.cbo.gov/publication/15515.

33 US Air Force, "B-21 Raider Accelerates Delivery." For a think tank examination of the topic, please see Walton and Patt, *Flipping the Script*, 61.

34 *Hearing on Posture and Readiness of the Mobility Enterprise* (testimony of Gen. Reed); *Hearing on Posture and Readiness of the Mobility Enterprise* (statement of Gen. Reed).

35 Diana Maurer, *Aerial Refueling Tankers: Air Force Needs More Focused Metrics and a Risk-Based Mitigation Plan to Improve Sustainment* (US Government Accountability Office, June 2026), https://www.gao.gov/assets/gao-26-109154.pdf.

36 Stephen Chen, "Chinese Scientists Plan Surface-to-Air Missile with 2,000 km Kill Range," *South China Morning Post*, March 28, 2024, https://www.scmp.com/news/china/science/article/3256914/chinese-scientists-plan-surface-air-missile-2000km-range.

37 Data are drawn from DefenceGeek (@DefenceGeek), "UPDATE: US Air Force Tanker Fleet 08/04/2026 (Ceasefire Day 1)," X, April 8, 2026, https://x.com/DefenceGeek/status/2041885421118869584/photo/1; DefenceGeek (@DefenceGeek), "UPDATED MAP - ORDER OF BATTLE," X, February 23, 2026, https://x.com/DefenceGeek/status/2025992367254196283/photo/1; and Walton and Clark, *Resilient Aerial Refueling*, 22; John G. Payne, *A Comparative Study of KC-135 Operations in Vietnam, Desert Storm, and Allied Force* (US Air Force Institute of Technology, 2000), 39–40, 62; T. Michael Moseley, "Operation Iraqi Freedom—By the Numbers," US Central Air Forces, April 30, 2003, https://www.globalsecurity.org/military/library/report/2003/uscentaf_ oif_report_30apr2003.pdf; Julia Denman, Walter Ochinko, Trisha Kurtz, Joy Labez, and Howard E. Kapp, *Operation Desert Storm: Aerial Refueling Operational Efficiency* (US General Accounting Office, 1993), 5; Margaret Romero, *Algebra of Tankers* (Air Force Institute of Technology, 2006), 3; Karl P. Mueller, Gregory Alegi, Christian F. Anrig, Christopher S. Chivvis, Robert Egnell, Christina Goulter, Camille Grand, Deborah C. Kidwell, Richard O. Mayne, Bruce R. Nardulli, Robert C. Owen, Frederic Wehrey, Leila Mahnad, and Stephen M. Worman, *Precision and Purpose: Airpower in the Libyan Civil War* (RAND Corporation, 2015), 88; and "Air Force Pamphlet 10-1403: Air Mobility Planning Factors," US Air Force, October 24, 2018, 18. The notional 2035 tanker airfield laydown and location of ARCPs assume a laydown that could sustain operations while maintaining attrition on the ground at 1 percent or less of the committed force per day. Estimated weighted averages for ARCPs are the weighted average of the different mission radii of refueling sorties from that base. For example, if at an airfield three sorties were flown to radii of 500 nmi, 1,000 nmi, and 1,500 nmi, then the weighted average would be 1,000 nmi. Due to the geographic distribution of airfields throughout the theater, the weighted average distance of ARCPs from airfields of 2,387 nmi in the 2035 scenario is less than might be expected for Pacific distances.

38 "The weighted average mission radius for aerial refueling tankers was 2,750 nmi. At that distance, single KC-135 or KC-46A tankers could deliver fewer than 50,000 lb of offload to receivers, which necessitated force extension missions in many cases." See Walton and Patt, *Flipping the Script*, 100, 149, 168.

39 This assessment considers airfields in the Indo-Pacific on US and Pacific allied territory, with at least approximately 18.6 million lb of fuel storage, which is enough to support the operations of a squadron of KC-46As for a week, and appropriate runway length, firmness, and parking space for those KC-46As.

40 This Red Attack Simulation is a Monte Carlo simulation with 100,000 trials. It takes a predetermined set of airfields that Red will attack over the course of seven days. Red has a fixed number of aircraft, missile launchers, and munitions. The simulation accounts for launch platforms and munitions performance and inventory, as well as airfield ramp space and distance from the PRC. At the beginning of each trial, a "strike list" is probabilistically made per range band, choosing which airfields to attack first. Munitions assigned to a band are assigned to attack that airfield until it is destroyed, upon which Red will move to attack the next airfield. This models how the PLA may organize overwhelming strikes rather than a random spread of strikes without focused suppression, leaving airfields damaged but still operational. There is an attack ceiling per band based on assumptions of PLA munitions stockpile usage, and there are assumptions made regarding the impact of Blue defenses on Red strike threats. Each airfield is assigned a number of strikes necessary to suppress it. When the threshold is reached, the airfield is considered suppressed. The presented video screenshot from the generated simulation shows the average of 100,000 trials and does not represent one trial. It is best understood as a risk assessment for airfields overall. One trial would feature complete suppression of some airfields, while leaving others completely operational, and a few partially damaged.

41 Walton and Patt, *Flipping the Script*, 38.

42 Walton and Clark, *Resilient Aerial Refueling*, 13.

43 Walton and Clark, *Resilient Aerial Refueling*, 9.

44 Walton and Clark, *Resilient Aerial Refueling*, 9.

45 Walton and Clark, *Resilient Aerial Refueling*, 44–45.

46 Walton and Clark, *Resilient Aerial Refueling*, 77.

47 Walton and Patt, *Flipping the Script*, 119.

48 Walton and Clark, *Resilient Aerial Refueling*, 47.

49 Cost estimate assumes $143.49/bbl for 1.2 million bbl of JP-5 and $141.97/bbl for 0.7 million bbl of Jet A-1. See *Defense Working Capital Fund, Defense-Wide Operating and Capital Budgets: Fiscal Year (FY) 2027 Budget Estimates* (US Department of War, April 2026), 128, https://comptroller.war.gov/Portals/45/Documents/defbudget/FY2027/budget_justification/pdfs/06_Defense_Working_Capital_Fund/PB_2027_DWWCF_Operating_and_Capital_Budget_Est.pdf.

50 Walton and Clark, *Resilient Aerial Refueling*, 47.

51 For more information, see Walton and Patt, *Flipping the Script*, 119.

52 For more information, see Walton and Patt, *Flipping the Script*, 77–82.

53 Jan Tegler, "Lack of Connectivity Possible Contributor to Middle East KC-135 Mishap," *National Defense Magazine*, April 27, 2026, https://www.nationaldefensemagazine.org/articles/2026/4/27/lack-of-connectivity-possible-contributor-to-middle-east-kc135-mishap.

54 Tegler, "Lack of Connectivity Possible Contributor."

55 Walton and Clark, *Resilient Aerial Refueling*, 49.

56 Walton and Patt, *Flipping the Script*, 61, 72; Tegler, "Lack of Connectivity Possible Contributor."

57 Matthew Cox, "Air Force Taps Industry to Study Active Defenses for Tanker Fleet," *Air and Space Forces Magazine*, July 2, 2026, https://www.airandspaceforces.com/air-force-industry-active-defenses-tanker-fleet/; Walton and Patt, *Flipping the Script*, 106.

Walton and Patt, *Flipping the Script*, 76.

58 Walton and Patt, *Flipping the Script*, 76.

59 Bryan Clark and Dan Patt, *Building a Team for Next Generation Air Dominance: Enabling Mission-Focused Teams Through Software-Defined Capabilities* (Hudson Institute, 2022), 27, https://www.hudson.org/national-security-defense/building-a-team-for-next-generation-air-dominance.

60 Clark and Patt, *Building a Team for Next Generation Air Dominance*, 27.

61 For a discussion of rapid Intelligence, Development, Operations cycles, see Bryan Clark, Ian Crone, and Dan Patt, *The Quick and the Dead: How Adaptation in Contact Drives Military Advantage* (Hudson Institute, 2026), 30, https://www.hudson.org/defense-strategy/quick-dead-how-adaptation-contact-drives-military-advantage-bryan-clark-dan-patt-ian-crone.

62 US Air Force, "Air Force, Boeing Accelerate KC-46 Upgrades to Target Readiness," news release, May 12, 2026, https://www.af.mil/News/Article-Display/Article/4484901/air-force-boeing-accelerate-kc-46-upgrades-to-target-readiness/.

63 For a discussion of boom/drogue hybrid systems, see: Walton and Clark, *Resilient Aerial Refueling*, 65.

64 Audrey Decker, "As Air Force Mulls Next-gen Fighter, Tanker Plans Hang in the Balance", *Defense One*, September 13, 2024, https://www.defenseone.com/technology/2024/09/air-force-mulls-next-gen-fighter-tanker-plans-hang-balance/399530/.

65 "Automated Air-to-Air Refueling," SAM.gov, July 25, 2025, https://sam.gov/opp/ccac72e33b2947159d8a7955ca8a6325/view; and "Small Hybrid Aerial Refueling Kit," SAM.gov, August 27, 2024, https://sam.gov/opp/54e816ad60a745a6a5b457a103e2441c/view.

66 Aaron A. Borszich, *Effects of KC-10 Divestment on Daily Competition Sortie Requirements* (Air Force Institute of Technology, 2020), 16.

67 Walton and Clark, *Resilient Aerial Refueling*, 23, 25–26.

68 Mike Minihan, *Beyond the Mobility Manifesto* (US Air Mobility Command, January 2024), 25, https://www.amc.af.mil/Portals/12/documents/AboutUs/Beyond%20the%20Manifesto.pdf.

69 In *Flipping the Script*, the planned Blue force faced a 20 percent gap in desired aerial refueling support. Within the simulation, to meter demand, only half of the potential sorties that could have used aerial refueling received it. Therefore, there was an approximately 40 percent gap in potential receiver refuelings, and only 60 percent of the potential demand was met. See Walton and Patt, *Flipping the Script*, 100.

70 In terms of crewing, the KC-46A and A330 MRTT+ were assumed to be manned; the Medium BWB design was assumed to be manned, with a high degree of autonomy and automation; the Medium Reduced Signature design could be unmanned or manned (and was modeled as unmanned); and the CTA was unmanned.

71 Author figure. The image of the Medium BWB is based on the Boeing ERA-009H1 concept in Quinlan and Gern, "Conceptual Design and Structural Optimization of NASA Environmentally Responsible Aviation (ERA) Hybrid Wing Body Aircraft." The image of the Medium Reduced Signature design is based on Boeing's "stealthy BWB," cited in Trevithick, "Stealthy Tanker-Transport Aircraft Concept Unveiled by Boeing."

72 KC-46A procurement cost is based on the FY 2031 Flyaway Unit Cost of $324.159 million ($299.473 million in FY 2027 dollars), plus $10 million in additional self-defense capabilities. See *Fiscal Year (FY) 2027 Budget Estimates: Air Force Justification Book, Aircraft Procurement*, 89. In terms of RDTE, it assumes a $1–$3 billion range for enhanced self-defense and other capability integration, using $2 billion for our cost modeling.

In terms of the A330 MRTT+ procurement, our costing assumes a base France/Spain-built A330 MRTT+ of $285 million, adds a US-build and US-requirements premium of $20 million to reach $305 million, and adds $10 million in enhanced self-defense capabilities for a total of $315 million. In terms of RDTE, it assumes a $1–$3 billion range for enhanced self-defense and other capability integration, using $2 billion for our cost modeling.

In terms of Medium BWB procurement, we used the cost per pound of the KC-46A (exclusive of $10 million in enhanced self-defense capabilities) and multiplied it by the empty weight of the aircraft to reach $228 million. We then doubled the $10 million additional cost of the KC-46A's enhanced self-defense capabilities to reflect an even more capable or better-integrated self-defense system and added it to the aircraft cost to reach a total of approximately $250 million. In terms of RDTE, we assumed a range of $6–$8 billion, using $7 billion for our cost modeling.

In terms of the Medium Reduced Signature design, we divided the F-35A APUC of $108 million (inclusive of the engine) by its weight to generate a cost per pound of $3,686. Then, reflecting that the design need not be as low-signature and in turn expensive as the F-35A, 0.8 of the F-35A's cost per pound is multiplied by the Medium Reduced Signature design's empty weight to reach a total APUC of approximately $295 million. Its RDTE range is $10–$15 billion, and $12.5 billion is selected.

In terms of CTA procurement, a business jet cost of $1,600 per pound is multiplied by the CTA's empty weight to reach an APUC

of approximately $80 million. Its RDTE range is $4.5–$7 billion, and the average of $5.75 billion is used for cost modeling.

73 Based on the work of John Stillion, we estimated the current KC-46A required an 800 nmi stand-back distance from threats. See Stillion, *Trends in Air-to-Air Combat: Implications for Future Air Superiority* (Center for Strategic and Budgetary Assessments, 2015), 49, https://csbaonline.org/wp-content/uploads/2026/03/Air-to-Air-Report-.pdf. Our analysis assumed that the additional self-defense systems were weight- and drag-neutral and did not lead to a reduction in available onboard fuel. If this were not the case, then the KC-46A option could carry less fuel than presented.

74 *Hearings to Examine Proposed Budget Estimates and Justification for Fiscal Year 2027 for the Department of the Air Force* (testimony of Gen. Kenneth S. Wilsbach).

75 US Department of State, "Qatar—KC-46A Aerial Refueling Aircraft," news release, August 20, 2026, https://www.state.gov/releases/bureau-of-political-military-affairs/2026/08/qatar-kc-46a-aerial-refueling-aircraft/.

76 *Fiscal Year (FY) 2027 Budget Estimates: Air Force Justification Book: Aircraft Procurement*, 89.

77 A similar support cost growth dynamic was observed with the Air Force's KC-10 tanker fleet as DC-10s were retired from commercial passenger and then freighter service.

78 Our analysis assumed that the additional self-defense systems were weight- and drag-neutral and did not lead to a reduction in available onboard fuel, such as through other weight savings. If this were not the case, then the A330 MRTT+ option could carry less fuel than presented.

79 "X-48 Hybrid/Blended Wing Body."

80 "Entities Identified as Chinese Military Companies Operating in the United States in Accordance with Section 1260H of the William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021 (Public Law 116-283, Section 1260H, as Amended)," US Department of War, June 8, 2026, 9, https://media.defense.gov/2026/Jun/08/2003945537/-1/-1/1/ENTITIES-IDENTIFIED-AS-CHINESE-MILITARY-COMPANIES-OPERATING-IN-THE-UNITED-STATES-IN-ACCORDANCE-WITH-SECTION-1260H.PDF.

81 Aircraft operating from airfields ≤1,000 nmi from the PRC only use up to 25 percent of potential working ramp space available in a contingency to military forces, since they disperse a great deal; aircraft operating from airfields 1,001–2,000 nmi from the PRC employ up to 50 percent; aircraft operating from airfields 2,001–3,000 nmi from the PRC employ up to 75 percent; and aircraft operating from airfields ≥3,001 nm from the PRC employ up to 100 percent.

82 Although short and vertical takeoff capabilities are important for many mobility and special forces missions, the marginal utility to tankers of accessing airfields with runways of less than 5,000 ft at full fuel loads seems low, and it would come at a great cost in terms of other desired performance parameters that address mobility challenges. If necessary, many tanker designs can take off from runways of airfields ≤5,000 ft or less at low fuel levels.

83 Walton and Patt, *Flipping the Script*, 61.

84 Noah Robertson, John Hudson and Susannah George, "Pentagon Weighing Smaller US Military Presence in Gulf Once Iran War Ends," *Washington Post*, August 18, 2026, https://www.washingtonpost.com/national-security/2026/08/18/pentagon-evaluating-smaller-us-military-presence-persian-gulf-after-iran-war/.

85 "Transcript: Secretary of Defense Pete Hegseth and Chairman of the Joint Chiefs of Staff General Dan Caine Hold a Press Conference," US Department of War, June 22, 2025, https://www.war.gov/News/Transcripts/Transcript/Article/4222543/secretary-of-defense-pete-hegseth-and-chairman-of-the-joint-chiefs-of-staff-gen/.

86 Phil Stewart, Idrees Ali, Joanna Plucinska, and Jonathan Landay, "US Bolsters Trump's Middle East Military Options by Moving Refueling Aircraft, Officials Say," Reuters, June 16, 2025, https://www.reuters.com/world/us/us-bolsters-military-options-trump-with-refueling-aircraft-officials-say-2025-06-16/.

87 Lieutenant General Alexus Grynkewich, commander, Air Forces Central / Ninth Air Force, discussed wanting to "flood the zone" with low-cost intelligence, surveillance, and reconnaissance drones. See Sean Carberry, "Just In: Air Force Advancing Command, Control in Middle East Fight," *National Defense Magazine*, April 3, 2024, https://www.nationaldefensemagazine.org/articles/2024/4/3/air-force-advancing-command-control-in-middle-east-fight.

88 Walton and Patt, *Flipping the Script*, 94.

89 Walton and Patt, *Flipping the Script*, 94.

90 Walton and Patt, *Flipping the Script*, 109.

91 Matthew Cox, "How the 2027 Budget Will Change the Air Force Tanker Fleet," *Air & Space Forces Magazine*, April 28, 2026, https://www.airandspaceforces.com/air-force-tanker-fleet-2027-budget/.

92 John Stillion and Bryan Clark, *What It Takes to Win: Succeeding in Twenty-First Century Battle Network Competitions* (Center for Strategic and Budgetary Assessments, 2015), 48–49, https://csbaonline.org/wp-content/uploads/2026/03/What-it-Takes-to-Win.pdf.

93 Hot refueling is "the transfer of fuel from a non-aircraft source (e.g., R-11 or approved fuel support equipment) into an aircraft having one or more engines running." See *Air Force Instruction 11-235: Flying Operations, Specialized Fueling Operations* (Secretary of the Air Force, May 31, 2019), 5, https://static.e-publishing.af.mil/production/1/af_a3/publication/afi11-235/afi11-235.pdf.

94 This assessment conducted 5,000 Monte Carlo trials for each tanker type to identify different combinations of up to 16 tanker airfields that could generate the required number of ARCPs using

up to 200 tankers. If an airfield was successfully selected in the simulation trial, it was included in the list. The total number of operable airfields is the summation of the airfields selected, rather than this number of airfields being simultaneously operable in any given scenario.

95 Walton and Patt, *Flipping the Script*, 100, note 168. Of note, "The weighted average mission radius for aerial refueling tankers was 2,750 nmi. At that distance, single KC-135 or KC-46A tankers could deliver fewer than 50,000 lb of offload to receivers, which necessitated force extension missions in many cases."

96 Walton and Patt, *Flipping the Script*, 107.

97 The simulation uses Blue 1's baseline force and laydown as a point of comparison. It assumes a 70 percent PMAI rate for tankers, that 25 percent of the PMAI fleet is held in reserve, and that 50 percent of the force dedicated to the campaign is engaged in non-simulation-relevant tasks (i.e., maintaining strategic deterrence, defense of the homeland, and other operations in other theaters). New tanker types are assumed to replace KC-135s on a 1:1 basis. The baseline total aircraft inventory consists of 239 KC-46A and 227 KC-135, which results in 63 KC-46A and 59 KC-135 employed in the simulation. In terms of Alternative 1, KC-46A and Medium BWB mostly operate in direct delivery mode, with some Medium BWB being force extended by KC-46A. In terms of Alternative 2, some KC-46A operate in direct delivery mode, while others act as parent tankers for child Medium Reduced Signature tankers that shuttle tank. In terms of Alternative 3, some KC-46A operate in direct delivery mode, while others act as parent tankers for child Collaborative Tanker Aircraft that shuttle tank. In terms of standback distances from threats, Medium BWB is assumed to be able to deliver fuel 200 nmi closer to threats than the KC-46A, Medium Reduced Signature is assumed to be able to deliver fuel 400 nmi closer to threats than the KC-46A, and Collaborative Tanker Aircraft is assumed to be able to deliver fuel 300 nmi closer to threats than the KC-46A. In terms of the simulation results, the Medium Reduced Signature design surprisingly generated a negative result in terms of the number of Red amphibious vessel loads that land on Taiwan as a result of it requiring a considerable number of KC-46A parent tankers to support its shuttling operations, which in turn reduces the number of KC-46A available to support other tasks. Although this result merits critical examination, it illustrates how shuttle tanking requires a significant number of parent tankers. See Walton and Patt, *Flipping the Script*, note 178.

98 Glen D. VanHerck, "Deter in Competition, Deescalate in Crisis, and Defeat in Conflict," *Joint Force Quarterly* 101, March 30, 2021, https://ndupress.ndu.edu/Media/News/News-Article-View/Article/2553378/deter-in-competition-deescalate-in-crisis-and-defeat-in-conflict/; and Cary Russell, Guy LoFaro, Usman Ahmad, Pamela Davidson, David Jones, Mae Jones et al., *Defense Transportation: DOD Can Better Leverage Existing Contested Mobility Studies and Improve Training*, (US Government Accountability Office, February 2021), https://www.gao.gov/assets/gao-21-125.pdf.

99 Mike Long, host, and Joel B. Vowell, guest, "On the Pacific, USARPAC, and China," *CLSC Dialogues*, China Landpower Studies Center, Strategic Studies Institute of the US Army War College, April 28, 2026, https://ssi.armywarcollege.edu/SSI-Media/Recent-Publications/Article/4472195/on-the-pacific-usarpac-and-china/.

100 Timothy A. Walton, Shane Dennin, and Sean Maxfield, *Indo-Pacific Infrastructure and Logistics* (working title; Hudson Institute, forthcoming 2026).

101 This was not only because of the Medium BWB's higher offload capacity, but also because the deployment planner was able to support more initial routes using its longer-range aerial refueling support. As a result, Red attacks on forward airfields did not as significantly stem the flow of Blue forces by forcing them to wait on the ramp at intermediate airfields, or cause Red attacks on intermediate airfields to block Blue passage. Then–US Air Mobility Command Commander General Mike Minihan expressed a desire for forces to "explode into the theater." See David Roza, "After Mobility Guardian, Minihan's Advice for His Troops: 'Be Demanding of Me,'" *Air and Space Forces Magazine*, September 11, 2023, https://www.airandspaceforces.com/minihan-mobility-guardian-lessons/.

102 Walton and Patt, *Flipping the Script*, 113–125.

103 The costing for this estimate assumes a conservative average Area Cost Factor of 1.87, a 10-year construction program, and 10 percent portfolio efficiencies from replicating similar projects at multiple sites, potentially using the same prime contractor or a set of contractors under a consortium. Large aircraft hardened aircraft shelters are assumed to be similar to the Andersen Air Force Base Air Expeditionary Force Forward Operating Location Aircraft Maintenance Hangar.

104 For more information, see Walton and Patt, *Flipping the Script*, 119.

105 Colton Jones, "US Air Force Gives KC-135 a Six-Year Connectivity Deadline," *Defence Blog*, May 15, 2026, https://defence-blog.com/u-s-air-force-gives-kc-135-a-6-year-connectivity-deadline.

106 Frank Wolfe, "Autonomous KC-135 Flight Testing May Begin Next Year," *Aviation Tech Today*, November 14, 2024, https://www.aviationtoday.com/2024/11/14/autonomous-kc-135-flight-testing-may-begin-next-year/.

107 For more information, see Walton and Patt, *Flipping the Script*, 105–106.

108 Michael W. Isherwood, "The KC-X Opportunity," *Armed Forces Journal*, September 1, 2007, https://armedforcesjournal.com/the-kc-x-opportunity/; and John A. Tirpak, "Risky Business," *Air Force Magazine* 92, no. 12 (December 2009), https://www.airandspaceforces.com/article/1209risky/. As another point of reference, in FY 2017, the KC-135 fleet flew 35,879 sorties yet only "hauled 385 tons of cargo." See Brian Brackens, "Team Helps Keep KC-135 Fleet Viable and Relevant," 88th Air Base Wing Public Affairs, US Air Force, May 2, 2018, https://www.aflcmc.af.mil/NEWS/Article-Display/Article/1906700/team-helps-keep-kc-135-fleet-viable-and-relevant/.

109 In the early Cold War, tankers were mostly based at airfields in the contiguous United States and were collocated with bombers.

Tankers started significantly supporting conventional forces at scale in the Vietnam War. During Operations Desert Shield and Desert Storm in 1990–91, the Air Force forward-deployed hundreds of tankers to support operations. The subsequent disestablishment of Strategic Air Command in 1992 and transfer of most tankers to Air Mobility Command marked the transition of the force's focus from one focused on maintaining strategic deterrence to power projection as part of a global mobility enterprise.

110 Using normalized mission profiles (airfield temperature, altitude, dry/wet conditions, flight path/altitude/time), the US Air Force should gauge the ability of designs to fulfill missions and campaign performance when taking off with various fuel levels. Singular takeoff field length numbers provide insufficient insight into the performance of designs, and hard constraints on takeoff field length numbers limit design options and do not provide sufficient insight into the ability of tankers to support desired missions vice simply takeoff.

111 Horacio H. Ghigliazza, Rodrigo Martínez-Val, Emilio Pérez, and Ladislav Smrcek, "Wake of Transport Flying Wings," *Journal of Aircraft* 44, no. 2 (2007): 558–562, https://doi.org/10.2514/1.24298; Paul Okonkwo and Howard Smith, "Review of Evolving Trends in Blended Wing Body Aircraft Design," *Progress in Aerospace Sciences* 82 (2016): 1–23, https://doi.org/10.1016/j.paerosci.2015.12.002.; Rodrigo Martínez-Val, "Flying Wings: A New Paradigm for Civil Aviation?" *Acta Polytechnica* 47, no. 1 (2007), https://doi.org/10.14311/914.;

112 Abdulrahman S. Almutairi, Hamad M. Alhajeri, Mohamed Gharib Zedan, and Hamad H. Almutairi, "Energetic and Exergetic Analysis of High-Bypass Turbofan Engines for Commercial Aircraft: Part I—Operation and Performance," *Aerospace* 13, no. 1 (2026): 27, https://doi.org/10.3390/aerospace13010027.

113 J. Ahuja, C. Perron, R. D. Bermudez Rivera, J. C. Tai, and D. N. Mavris, "Comparison of Blended Wing Body and Tube-and-Wing Performance Characteristics," *The Aeronautical Journal* 129, no. 1337 (2025): 1764–1790, https://doi.org/10.1017/aer.2025.8.

114 KC-46A procurement cost is based on the FY 2031 Flyaway Unit Cost of $324.159 million ($299.473 million in FY 2027 dollars). We estimate an additional $10 million or more in self-defense capabilities would likely be required for an improved KC-46A. See *Fiscal Year (FY) 2027 Budget Estimates: Air Force Justification Book: Aircraft Procurement*, 89.

Notes

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