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Policy Paper



Key Points

Resources are stretched thin, mission demand is on the rise, and key mission areas require recapitalization. The Air Force must prioritize solutions that yield maximum mission value and not rely on overly simplistic metrics, like cheapest per-unit acquisition cost or individual cost-per flying hour, as these may actually drive more expensive, less capable solutions.

Cost-per-effect is an assessment measure that affords the ability to assess the “business cases” behind comparative technologies through the operational lens of enterprise mission effectiveness and fiscal efficiency, not just lowest up-front per-unit cost for a piece of equipment that may only address one facet of the kill chain.

Cost-per-effect assessment should be adopted and applied across the Department of Defense as the preferred measure of merit in evaluating weapon system choices, especially as multiple services offer different solutions to achieve similar effects.

Congress should consider including language in the National Defense Authorization Bill requiring DOD to devise new measures to assess cost-per-effect for key mission areas, then implement such evaluations in the future force development process.

Resolving America’s Defense Strategy-Resource Mismatch: The Case for Cost-Per-Effect Analysis

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Abstract

Building the most effective, efficient Air Force demands focusing on solutions that realize best mission value. Wars are not won by lowest-cost bidders. They are won by applying more capable systems in innovative ways to best achieve desired outcomes or effects, not over emphasize input measures like unit cost, cost per flying hour, or total sustainment cost over the lifetime of a program.

While this seems obvious, a continued narrow focus on certain quantitative metrics would strongly suggest otherwise. Indeed, “effectiveness” has largely been missing from the goal of cost-effectiveness in procuring military systems. Though well-intentioned, this approach too often yields capabilities that drive more expensive, less capable combat options in an operational context.

Looking to future investments, the concept of “cost” needs to focus less on individual systems and more on the enterprise resources required to achieve mission goals. This means implementing a “cost-per-effect” metric. For the purposes of this policy paper, a cost-per-effect assessment measures the sum of what it takes to net a desired mission result, not just a single system’s acquisition and support costs without necessary context surrounding the capability’s actual use. For instance, F-35s, B-21s, and other advanced weapon systems may appear more costly on a per-unit basis than less-capable legacy aircraft designs, but enterprise assessments illustrate their potential to complete mission objectives more efficiently and capably, lowering overall operational expense. As such, they are a far more cost-effective option.

Introduction

In an era defined by increased risk amidst a burgeoning set of national security challenges, the United States Air Force (USAF) is attempting to rebuild its capabilities on a scale not seen in decades. This is an exceedingly important effort, given the Air Force currently fields the smallest and oldest aircraft inventory in its entire history. This situation is becoming untenable as combatant commanders around the world continually demand more Air Force assets. The choices made today will have a fundamental impact on the options

available to U.S. national security policymakers well into the future. Fiscal realities precipitated by COVID-19 will make an already difficult modernization challenge even harder.

To counter these national security concerns, the Air Force must prioritize solutions that yield maximum mission value, not rely on overly simplistic metrics, like cheapest per-unit acquisition cost or individual cost-per flying hour.

Such evaluations may actually drive more expensive, less capable solutions. In an era where technology is radically redefining how the Air Force secures mission effects, how effectively and efficiently a weapon system can accomplish mission requirements is a more important metric. Using four aircraft to successfully execute a mission is far more efficient than using forty, even if the latter involves lower-cost planes. This value analysis method is known as “cost-per-effect” assessment.

Air Force leaders have been advocating for requirements-based force structure growth for several years. In a September 2018 speech, then-Secretary of the Air Force Heather Wilson issued a stark

Key Terms

Cost-per-effect: The total cost involved with achieving a specific mission outcome. This includes mission aircraft to execute the actual task, as well as direct support assets. These include aerial refueling tankers, electronic jamming platforms, and surface-to-air missile suppression efforts. It also includes aircrews and requisite infrastructure like basing and related maintenance support.

Per-unit acquisition cost: The cost of procuring an individual aircraft, relevant armament, etc.

Cost-per-flying hour: The hourly cost involved with flying a single aircraft tied to its consumables, such as fuel, associated maintenance expenses, and aircrew costs.

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warning: “The Air Force is too small for what the nation expects of us.”¹ One year later, Air Force Chief of Staff General David Goldfein reiterated the same point: “The Air Force is too small for what the nation is asking us to do.”² As the service enters the new decade, this mismatch between real-world operational demand and the USAF’s force structure capacity will persist, given the likelihood of increasingly constrained defense budgets in the wake of COVID-19 fiscal driving factors. Dollars spent must deliver maximum returns because U.S. defense budget constraints will likely not correlate with adversary activities—circumstances described by the National Defense Strategy as “a security environment more complex and volatile than any we have experienced in recent memory.” This shortfall must be addressed in a concerted, prudent fashion where dollars expended yield maximum returns.³

The reality is that nearly every form of U.S. joint power projection relies on effects delivered by modern air forces: air superiority; the kinetic or non-kinetic destruction of targets; air mobility; persistent intelligence,

surveillance and reconnaissance (ISR); and secure command and control (C2). It is not an overstatement to say that when it comes to conducting joint force operations, the Air Force is the indispensable actor—every joint force operation involves some element of the Department of the Air Force (DAF). The same cannot be said of the other services. It is imperative to prioritize investments in future DAF aerospace capabilities that will yield outsized mission effects. U.S. national security leaders should seek procurement choices and associated concepts of operations in the aerospace domains that will provide greatest mission value in the types of conflicts in which the nation will likely engage. Harnessing an analytical approach known as cost-per-effect assessment is an important step toward ascertaining these best-value choices.

While this report views procurement through an Air Force lens, cost-per-effect assessment should be adopted and applied across the Department of Defense (DOD) as the preferred measure of merit in evaluating weapon system choices. This is especially important as multiple services offer different solutions to achieve similar effects. Cost-per-effect is a useful tool to explore comparative “business cases” behind each approach and prioritize those that offer better mission effectiveness and fiscal efficiency. Current measures favor lowest up-front per-unit cost (an “input” measure) for a piece of equipment that may only address one facet of the kill chain without taking into consideration the mission-effectiveness of the particular system (an “output” measure). Congress should consider including language in the National Defense Authorization Bill requiring DOD to devise new measures to assess cost-per-effect for key mission areas and then implement such evaluations in the future force development process.

The Current State of Play: A Focus on Unit Cost or Operating Costs is Not Enough

Today, U.S. defense leaders evaluating options to meet military requirements place great emphasis upon the traditional quantitative costs of a weapon system when deciding relative merit. As far as combat aircraft are concerned, this includes total program cost, unit cost, and the cost per flying hour of the designs in question. While these may be relevant metrics in some cases, they fail to account for an aircraft’s ability to achieve specific desired battlespace effects. A World War II-era P-51 costs substantially less to buy and fly than an F-22, and, while they are both fighter planes, the mission effects each can achieve are vastly different.

To this point, in a recent Congressional hearing, a senator expressed concern regarding the F-35’s hourly operating cost, explaining that “it comes down to an issue of numbers: the Air Force would like to see 1,763 F-35 aircraft, but if it costs \$35,000 an hour, how can we afford that going forward?”⁴ While the senator cited an accurate cost per flying hour figure at the time, his narrow focus on hourly operating cost missed the broader issue of value. If superior technologies and design allow F-35s to secure mission effects that would otherwise take multiple, less capable aircraft to achieve (and at higher risk), then F-35s will actually drive value across many dimensions of the greater warfighting system. Instead of unit or flight hour costs, it becomes more appropriate to consider what it takes to execute missions and secure objectives.

It is also important to recognize that overly narrow definitions of cost could find commanders equipped with a completely inadequate force. If aircraft are selected primarily to achieve up-front cost savings, they may lack the attributes required to win in high-intensity combat—a disastrous result.

As Dr. William LaPlante, who recently served as Assistant Secretary of the Air Force for Acquisition, explained:

We need to watch overreliance on traditional units of assessment. For example, while cost per flying hour is a common metric often cited when describing the expense associated with given aircraft, such measures are far from infallible. For example, we actually saw cost per flying hour decrease during sequestration because we were flying less. Modern operations—including 5th generation technology and distributed family of systems approaches—require a far more rational and informing cost-capability analysis.⁵

Making procurement choices informed by cost-per-effect analysis will increase combat power and achieve greater overall efficiencies. This is especially true for weapon systems that will operate as part of a team or a system-of-systems. Few combat aircraft undertake missions in a unilateral fashion. Normally, they function as a collaborative group. As Dr. LaPlante highlighted, this will be increasingly true in an era of highly networked operations applying concepts like Joint All Domain Command and Control (JADC2) and Mosaic Warfare.⁶

The scale of those teams and associated overall costs to achieve a particular mission effect are predominantly driven by technologies, such as propulsion plants, information processing systems, degree of low-observability, and required ground support infrastructure. If newer, more advanced aircraft like the F-35 and B-21 can successfully meet mission goals with smaller teams and less support overhead, the overall cost for specific missions will be far smaller

than using less-capable aircraft that require more support to achieve mission goals and survive against advanced threats. As one U.S. 5th generation fighter pilot explained, “Five to eight years ago, we would plan an entire force package of [4th generation] aircraft, about 20–30 aircraft, all to maybe have a slim hope of taking down a modern surface-to-air (SAM) threat—just one SAM. Now, we train to accomplish the same mission with far greater certainty using just a few F-35s, while continuing to execute a host of other taskings.”⁷

This concept is not new. On the first night of Operation Desert Storm, 20 F-117s struck 28 separate targets. Their stealth design gave them the ability to penetrate enemy air defenses without the need to rely on a large number of escort aircraft to provide defensive support. Moreover, precision strike technology allowed the F-117s to hit their targets with great lethality—they used one or two bombs per target. This relative value is significant, considering that the first non-stealth aircraft attack package required 41 planes, of which only eight dropped bombs, to hit a single target during the same exact timeframe. These eight non-stealth strike assets required multiple escort aircraft to jam hostile air defense radars, suppress surface-to-air missile (SAM) threats, and counter enemy fighters.⁸ So, while each legacy, non-stealth strike aircraft was less expensive than a stealth F-117 from a unit cost perspective, the fact that it took so many of them and a large package of supporting aircraft to accomplish a single task realized exceedingly high operational costs. The significantly larger number of associated aircrews, sustainment costs, logistical support, and basing requirements for such a large enterprise also substantially drove up total costs. The F-117s, by comparison, yielded superior mission value during Desert

Storm by flying less than 2 percent of the air campaign's combat sorties, but striking over 40 percent of the fixed targets.⁹

Given this context, U.S. national defense decisionmakers should increasingly focus on cost-per-effect as a key performance parameter (KPP) for new weapon systems as part of the acquisition competition process, specifically the Joint Capabilities Integration and Development System (JCIDS).¹⁰ KPPs are system capability requirements that must be met in order to realize operational goals. However, value does not derive from spending the least amount of dollars for a given system. Wars are not won by lowest-cost bidders or input measures like unit cost, cost per flying hour, or total sustainment cost over the lifetime of a program. They are won by applying more capable systems in innovative ways based on desired outcomes or effects. Investing in new capabilities and associated concepts of operation that reduce total cost drivers—such as delivering bombs on target, achieving a required degree of air superiority, or gathering information across the battlespace—will yield the greatest cost-per-effect.

Factors to Consider in Cost-Per-Effect Assessments

DOD cost-per-effect (CPE) assessments of future high-end capabilities should predominantly focus on peer conflict because the National Defense Strategy emphasizes deterring, or if necessary, defeating, great power aggression. To narrow the scope of discussion, the following list summarizes some of the key factors to consider in CPE assessments of future Air Force air superiority and strike combat systems aimed at the high end of the threat spectrum. These factors would apply to both mission areas, which are highly interrelated and can be accomplished by modern multi-role combat aircraft. Other mission areas

Key Performance Parameters

Key Performance Parameters (KPP) are system capability requirements that must be met for that system to meet its operational goals.

KPPs contribute to achieving the desired operational capability in a threshold and objective format. Each KPP is supported by operational analysis that considers technology maturity, fiscal constraints, and schedule before determining threshold and objective values.

would have different assessment points that could be evaluated to derive best mission value given relative cost.

1. *Precision effectors (both kinetic and non-kinetic)*: The more a discrete resource (i.e., kinetic bombing, cyber-attack, electronic warfare) focuses on an aimpoint and nets a specific desired effect, the greater the chance of mission success. This streamlined approach reduces the demand for redundant or robust force support.
2. *Survivability*: Ensuring that an aircraft can execute its tasks safely and return to its base ready for a future mission reduces attrition concerns and the need for reserve inventory aircraft. The more an aircraft can organically ensure its own survival within the existing battle network, without the need for additional support in the form of air superiority and electronic warfare escorts, the more cost-effective the strike package and the more aircraft can be tasked to meet other priority objectives.
3. *Fifth-Generation attributes of stealth, electronic warfare, sensors, processing power, communication links, fusion engines, and real-time command and control (C2)*: Too often incorrectly derided as “gold plating,” these

attributes greatly increase force effectiveness and efficiency by ensuring available combat tools can partner in a highly supportive fashion to maximize combined strengths, while minimizing vulnerabilities. A choice not to invest in these capabilities will drive significantly higher force structure requirements such that the Air Force will not be able to meet national defense strategy objectives.

4. *Aircraft range and payload*: Missions that must be executed over significant distances, entail long in-flight loiter times, or involve attacking a large number of targets per sortie are often more efficiently served by aircraft with long ranges and large payloads.

Given the number of recapitalization programs currently underway, it is critical to consider the cost-per-effect model as a far more accurate means of securing the best value for effective combat capabilities. As General Goldfein recently summarized, “Our focus is on setting the foundation for the Air Force we know we need with the technology and people we need to win when the nation calls upon us to do it.”¹¹ This perspective is not limited to the Air Force; it also demands attention from the Department of Defense, Office of Management and Budget, Congress, and the broader defense community of experts. Cost-per-effect assessments should also extend to other domain systems when determining which approach yields the most favorable business case—i.e., ground-based long-range fires should be evaluated in parallel with their aerial and sea-based counterparts. With resources increasingly strained, it is crucial to ensure the most prudent solutions receive prioritized funding. This is precisely why

the acquisition community should consider measuring cost-per-effect as a fundamental element in DOD’s requirements process: it would promote the creation of more innovative designs. To optimize capabilities across the entire set of required missions, in the future—particularly as DOD budgets decline—DOD must consider desired mission outcomes across all services.

The following sections analyze how cost-per-effect has evolved in a pragmatic operational context from the perspectives of precision strike, survivability, 5th generation technology, and range/payload attributes.

The Case for Precision: It All Comes Down to Hitting the Target

Whether striking an aimpoint with a bomb, launching a missile against an air-to-air target, or seeking to secure a non-kinetic effect through electronic or cyber warfare, campaign objectives and overarching force efficiency will radically improve when a specific action can be tied to a desired effect. Nowhere is this better exhibited than with the emergence of precision weaponry in the Vietnam conflict. Between 1966 and 1968, aircraft dropping unguided munitions on specific targets achieved an accuracy rate—termed “circular error probable” (CEP)—on average of about 420 feet. That meant that half the bombs dropped in that period fell within 420 feet of their targets and the other half impacted outside this radius. This lack of precision forced air commanders to use large force packages of bomb-carrying combat aircraft and multiple strike missions to ensure a target was destroyed. In other words, commanders had to rely on mass to make up for the lack of precision to ensure enough bombs would hit a target and achieve a desired degree of destruction. Aircrews often had to fly many strike missions until a target was confirmed as destroyed. Not only were these repeat missions incredibly costly in

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terms of the number of aircraft involved, loss of aircrews, the expenditure of consumables like fuel and weapons, and general wear and tear on aircraft components, they also placed airmen and their aircraft at higher risk in hostile air space. Increased aircraft and aircrew attrition meant the Air Force had to sustain higher equipment and personnel margins to backfill losses. Despite this use of mass, objectives were often not met in a timely fashion.

Starting in 1968, Air Force aircraft began to use laser-guided and electrical electro-optically guided munitions known as “smart bombs” that could achieve CEPs of about 30 feet.¹² The real-world impact of these new technologies was immense. The struggle to take down the Thanh Hoa Bridge in North Vietnam between 1965 and 1972 is one example that demonstrates the game-changing value of precision strike technologies. This bridge served as a central logistical artery allowing communist Vietnamese forces to move supplies throughout their nation. The first U.S. Air

Force mission flown against the bridge was launched on April 3, 1965 as part of a two-day planned set of strikes. The first day's strike package consisted of 46 F-105s with unguided bombs, 21 F-100s providing air cover, two McDonnell RF-101s to execute bomb damage photo reconnaissance, and 10 aerial tankers dedicated to refueling the strike package in flight. The mission failed to destroy the bridge at the cost of two U.S. aircraft shot down and another severely damaged. A strike mission was launched the following day comprising a similar force package, resulting in the loss of another two aircraft without dropping the bridge. Over the following seven years, American combat aircrews flew

an additional 871 sorties against the bridge without success and at the cost of another 11 aircraft lost to enemy defenses. It was not until a mission on May 13, 1972—over seven years later—that a single strike package of 14 F-4s using laser-guided bombs succeeded in destroying the bridge.¹³

This was not the only guided weapons success story of the Vietnam conflict. Between April 6 and June 30, 1972, the Air Force's 8th Tactical Fighter Wing succeeded in destroying 196 separate bridges using guided munitions.¹⁴ These successes gave birth to the notion of “one bomb, one target,” which became an accepted planning factor as more advanced precision-guided weapons emerged over ensuing years to give American airmen the ability to strike nearly any target day or night and in all weather conditions with precision.

This example illustrates that precision guidance is now a vital attribute required to meet objectives for strikes and other missions in an effective, decisive, and efficient fashion. The bar charts below illustrate a *cost-per-effect* comparison that is loosely based on the Thanh Hoa Bridge example.¹⁵ As is plain to see, the single precision-enabled strike package is far more effective and efficient from a cost-per-effect perspective than the 900 strike sorties using

The Value of Decisive Effects

Wartime success demands the rapid elimination of key points in an adversary's war-making enterprise in a decisive fashion. Failing this, opposing forces gain the advantage of time to reappportion their forces and facilitate fallback solutions. The conflict will drag on longer, costs of waging war will rise, more friendly forces will be put at risk, and the ultimate chance for victory may fade. The U.S. military is no longer designed to execute these sorts of conflicts. The ability to master precision targeting is a fundamental advantage required to deny the enemy such advantages.

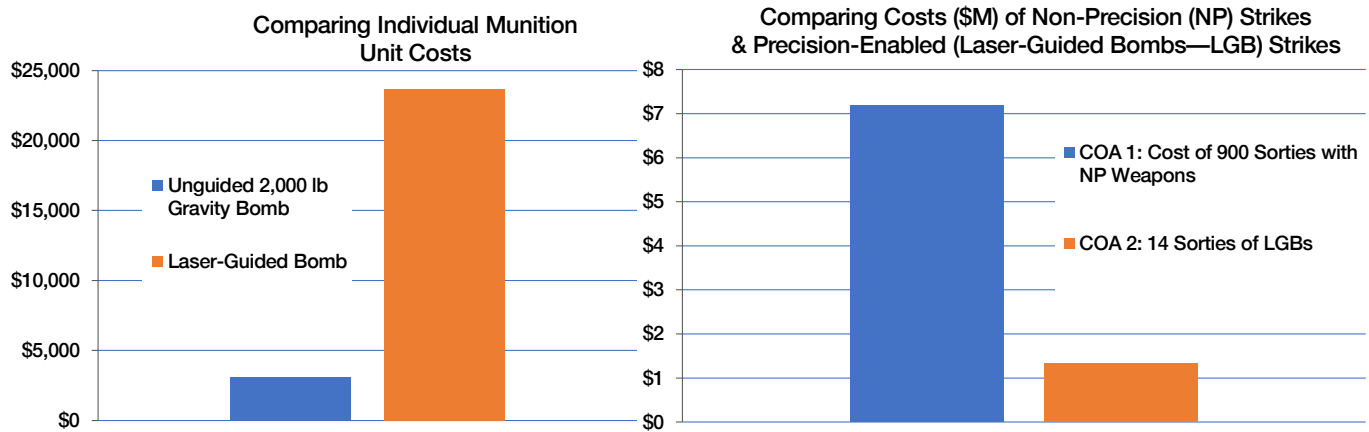


Figure 1: The first bar chart compares the estimated unit cost of a single non-precision “dumb bomb” with the greater estimated unit cost of a Vietnam-era laser-guided bomb. The second bar chart represents the total estimated cost of dumb bombs expended by some 900 strike sorties against a notional Vietnam-era target, which is then compared to the cost of the smart munitions carried by 14 F-4 sorties to destroy the same notional target. The replacement cost of 15 fighter aircraft lost to enemy defenses in COA 1 is estimated at an additional \$36M (for F-4s in 1965 TY\$).

dumb bombs. However, comparisons that focus only on the unit costs of individual munitions alone—the left bar chart—would tell a far different story. A truly useful comparison would also include other factors, such as the opportunity costs of obligating aircraft and crews to so many unsuccessful missions as well as the logistical costs of generating sorties. In short, the rudimentary cost-per-effect assessment in this example reveals that while the unit cost of laser-guided munitions exceeded the cost of similarly sized unguided bombs, the effectiveness of smart weapons drove tremendous mission efficiencies.

Over the ensuing decades since Vietnam, precision weaponry has grown far more effective. Air planners at all levels—strategic, operational, and tactical—expect it. It is a baseline assumption that has fundamentally changed the ways in which air campaigns are waged. As one Air Force pilot explained:

Precision targeting opens a host of options that otherwise would not be available with unguided munitions. You give senior leaders the ability to pursue dynamic targets in vehicles and on foot; strike targets in narrow alleyways or canyons; or even in specific rooms within a multi-tiered building.¹⁶

However, maintaining this precision strike advantage cannot be taken for granted. Adversaries have observed the power of precision and have spent considerable time, energy, and resources toward countering it. Their efforts include seeking to degrade weapons guidance tracking through efforts such as global positioning satellite (GPS) jamming, deeply burying and hardening important facilities, or seeking to actually shoot down the munitions in flight. U.S. defense leaders must continue to press forward with new technologies to ensure strike advantage is not lost.

This is why 5th generation combat air technologies that integrate multiple sensor nodes, collaborative systems, and tremendous processing power to identify targets and ensure their destruction despite an enemy’s defensive measures is so important. Airstrikes in the era of peer-to-peer conflict largely come down to knowing with great accuracy what to strike, having the means to transmit that information to relevant combat platforms and their munitions, and create multiple redundant pathways to achieve desired effects upon targets to overcome adversary defenses.

A defense policy or budget official seeking to understand the true cost of precision in the modern era must also understand key factors such as: 1) how

modern strike packages are assembled; 2) alternate approaches to accomplish a mission and the holistic costs of all assets needed to net an objective; 3) the cost of potential restrikes, and 4) the risk and costs of incurring losses during a mission. As is illustrated by the Vietnam conflict example, overly biasing acquisition decisions on the potential unit cost of an individual weapon (or the cost of acquiring an aircraft alone) risks leading decisionmakers to choose seemingly inexpensive capabilities that will actually drive gross inefficiencies in future operations.

The Case for Survivability

The imperative to execute a mission, safely return to base, and fly again tomorrow is a common-sense objective as old as air warfare itself. Aircraft shot down by an enemy must be replaced and new aircrews trained to take the place of those lost. Large-scale attrition can rob commanders of the ability to secure multiple concurrent effects in a decisive fashion because they simply lack the means to do so. At an extreme, operations can fail to quickly defeat an act of aggression because attrition deprives commanders of the resources they need at the most critical time to net decisive results. This can lead to extended wars of attrition, which may undermine the ability to secure victory.

This is exactly what happened to the 8th Air Force during World War II in the European Theater of Operations. In 1942 and 1943, stiff German resistance resulted in a high number of American bomber losses. The U.S. industrial base lacked the capacity to supply the 8th Air Force with enough replacement aircraft, and the Army Air Force's aircrew training pipeline was strained to the limit to meet overwhelming wartime demand. As 8th Air Force Commander General Ira Eaker later explained:

It became my duty to make certain that we did not, through unwise or careless or hasty action, sacrifice our whole force. We could have taken, say, our first 100 bombers at such a rate and against such [long] distance targets that we would have lost them all in ten days, because on some of those targets we lost 10 percent on a mission. But I always said and reported to General Arnold that I would never operate that force at a rate of loss which we could not replace.¹⁷

One problem with this approach is that a warfighting strategy that is overly driven by the need to preserve force structure is far different than a strategy that is designed to win as quickly as possible. Survival becomes the objective, not victory. Moreover, it can create opportunities easily exploited by an enemy.

The drive to develop stealth and other technologies to improve the survivability of Air Force aircraft can be traced back to the need to counter Soviet-era air defenses. For instance, throughout the Vietnam conflict American combat aircraft suffered from high loss rates in operations against a third world country equipped with defensive armaments provided by the Soviet Union. One of the starkest examples illustrating the severity of these threats occurred in the final air campaign of the conflict, Operation Linebacker II. During this December 1972 operation, the Air Force lost 15 B-52 heavy bombers in 12 days to the Soviet-built SA-2 SAM system.¹⁸

Less than a year after Linebacker II, Soviet-built air defenses cost Israel 102 combat aircraft out of an inventory of 390 in the Yom Kippur War, which lasted less than a month. Of particular concern to U.S. defense officials, 32 of these downed aircraft were F-4 Phantoms, and 53 were

A-4 Skyhawks, fighters that comprised a significant percentage of the U.S. combat aircraft inventory at the time. U.S. commanders applied this loss rate to an assessment of a potential European conflict with the Warsaw Pact and concluded that a similar loss rate would expend the U.S. Air Force's combat aircraft inventory after two weeks.¹⁹ One defense analyst at the time remarked:

*[This war has] put a big question mark over [NATO's] ability to wage anything but the shortest of conventional wars. Certainly, rates of attrition cannot be expected to be any less high in a war in Europe; and it would be a tragedy not merely for the West but for mankind if NATO, after holding its own tactically, were to be faced with the choice of either surrendering or initiating a nuclear exchange because of insufficient reserves.*²⁰

The takeaway from Linebacker II and the Yom Kippur War was clear: the survivability of U.S. combat aircraft needed to increase markedly. This increased DOD's impetus to develop stealth aircraft with outer mold line (OML) shaping, special radar absorbent coatings, and other technologies that would prevent Soviet air defense systems from completing their find, fix, track, and target kill chains to achieve a successful intercept.

The record for stealth aircraft has been truly remarkable. The first combat aircraft of this type, the F-117, only suffered one combat loss in its entire operational history

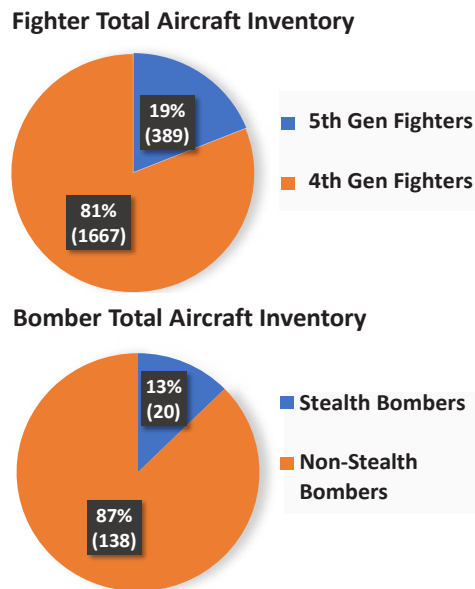
against complex defensive systems that were far more advanced than those used during the Vietnam and Yom Kippur conflicts. The B-2 bomber, the second operational stealth aircraft fielded, has never experienced a combat loss despite regular use during some of the most dangerous phases of several post-Cold War operations, including during the opening hours of conflicts when defenses were at their peak of lethality.

Subsequent stealthy designs took shape in the form of the F-22 air superiority fighter, the F-35, and the future B-21 bomber. Instead of relying primarily on low observable signatures to avoid detection by enemy sensors, the current generation of stealthy aircraft also have tremendously powerful sensors that help their pilots to understand threats in the battlespace and constantly manage their relative positions to reduce their exposure to points of danger. They are also equipped with advanced electronic warfare technologies that can jam and deceive enemy defenses. While no stealth aircraft is truly "invisible," the standard set by this 5th generation technology is impressive. U.S. stealth aircraft are the envy of air forces around the world, and it is not a coincidence that allies and adversaries alike are working to develop and field similar technologies.

Despite the obvious operational advantages of stealth, DOD airpower inventories lack sufficient stealth capacity to challenge peer competitors—just 20 B-2s, 186 F-22s, and less than 300 F-35s are presently fielded. This contrasts with several thousand non-stealth airframes. Currently, the USAF fighter aircraft inventory mix is about 80 percent non-stealth to 20 percent stealth.²¹ For more than a decade after the end of the Cold War, the absence of a peer competitor prompted a number of U.S. national defense leaders to assume that future air operations could be conducted by non-stealth air forces at an acceptable

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Figure 2:
 Less than 20 percent of U.S. fighter/attack aircraft are 5th generation. Only 13 percent of U.S. bombers are stealthy.



degree of risk. Moreover, funding for additional attrition aircraft inventories and a pilot training pipeline that could surge to replace combat casualties was sacrificed to realize budget efficiencies.

This mindset was demonstrated by the decision to prematurely curtail B-2 stealth bomber procurement to 21 airframes at the end of the Cold War from an original planned buy of 132 aircraft, as well as several years later when leaders capped the F-22 program at 187 aircraft instead of the validated military requirement for 381 stealth fighters. In both cases, the perceived lack of a threat and the cost of stealth aircraft were cited as a major reason for the cancellations. Looking back at the B-2 experience, former Secretary of Defense Robert Gates explained, “By the time the research, development, and requirements processes ran their course, the aircraft, despite its great capability, turned out to be so expensive.”²²

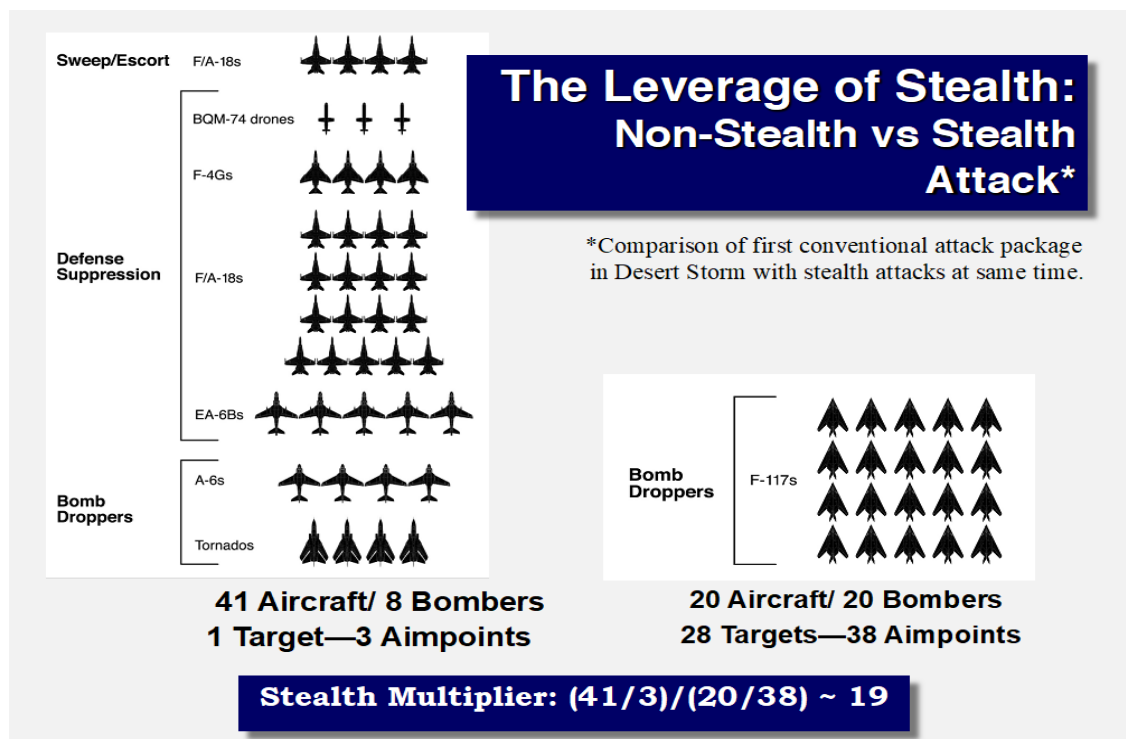
Regarding cost alone—with no consideration of combat effectiveness—Secretary Gates was correct, historically speaking. Stealth aircraft have not been inexpensive on a per-unit basis compared to legacy non-stealth aircraft designs.²³ However, the B-2 and F-22 decisions were

not informed by *cost-per-effect capability assessments* that compared the potential of stealth aircraft against other non-stealth capability options for operations in threat environments that were already becoming more contested. Nor did DOD assessments adequately weight the F-22’s and B-2’s potential to markedly reduce enterprise costs by effectively projecting air combat power at a time and place of America’s choosing without relying on very large packages of supporting aircraft that are typically needed to counter enemy defenses and reduce non-stealth aircraft attrition.

The value of considering these cost-per-effect factors is again illustrated by the example cited earlier of the 41 non-stealth aircraft that were allocated to strike a single target on the first night of Operation Desert Storm. Of these 41 aircraft, only eight of them dropped munitions on the target; the rest were engaged in providing air cover, suppressing SAMs, and affording electronic warfare support. In just one launch period in the same timeframe, 20 F-117s struck 28 separate targets without any protective escorts thanks to their stealth technology.²⁴ An arithmetic comparison indicates that it took 19 legacy aircraft to execute what it took just one F-117 to achieve. Furthermore, procuring, manning, sustaining, basing, and operating the legacy aircraft costs far more than a single F-117. Under this cost-per-effect lens, the non-stealth aircraft were far from the lowest-cost capability option.

The takeaway is simple: aircraft survivability matters—big time. Decisionmakers should factor this into their acquisition decision calculus by considering whether candidate aircraft can execute missions that span the full operational spectrum in future threat environments. If they cannot, then their decreased utility must be factored as a tax upon the remaining force, since additional aircraft are necessary to complete the mission. Factors such as the number of required

Figure 3:
Comparing Stealth
and Non-Stealth Aircraft



protective escorts and other measures needed to counter enemy defenses increase the total cost of capability alternatives. As potential adversaries field more advanced defensive technologies, it will be crucial for U.S. defense leaders to understand that the combination of stealth, networked all-domain sensors that provide situational awareness, and advanced electronic warfare capabilities will remain the baseline for U.S. air operations. The

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force protection requirements for older, non-stealth aircraft designs are growing, and targets and other operational objectives accessible to them are rapidly diminishing. In future capability competitions, instead of simply declaring an aircraft's unit cost as "too expensive," it is crucial to explore the value it could provide in realistic mission constructs and then compare it against the value associated with seemingly "less-expensive" alternatives. Aircraft survivability must be a key part of this evaluation.

The New Imperative: 5th Generation Aircraft Technologies

Fifth-generation stealth fighter aircraft like the F-22, F-35, and eventually the next generation of stealth bomber, the B-21, are best recognized for their low observable shapes, high performance, and, as anyone who has been reading the headlines for the past several years will know, for their supposed high unit costs. Headlines like "Inside America's Dysfunctional Trillion-Dollar Fighter-Jet Program" speak to the price tag-centric skepticism that many have regarding the types of aircraft that are slated to comprise the vast majority of America's next-generation combat air force.²⁵

The assessments of those who fly these aircraft, however, are in sharp contrast to the opinions of 5th generation skeptics. In the words of one F-35 pilot, "What was once nearly impossible has become commonplace with the advantages brought by 5th generation aircraft like the F-35."²⁶ There are three key attributes of 5th generation aircraft behind these assessments: 1) their

survivability; 2) their unmatched mission performance; and 3) their ability to gather tremendous quantities of information, process it, fuse it with data pulled from offboard sources, and then display highly intelligible actionable knowledge to a pilot—as opposed to disparate, cryptic technical data. The combined net effect of these attributes are significant gains in combat effectiveness.

These performance-boosting attributes are highly interrelated. For example, the stealth characteristics of 5th generation fighter aircraft paired with advanced electronic warfare systems increase overall survivability. Added to this, sensor technology allows pilots to understand the battlespace so that they can best position themselves to minimize vulnerability to enemy defenses. Fighters like the F-22 and F-35 can also harness speed and maneuverability to evade enemy defenses. Take away one of these key attributes, like low observability, and the effectiveness of other attributes erode substantially. The synergy of these attributes is what achieves a better cost-per-effect.

One key strength that stands above all others in explaining the value afforded by 5th generation aircraft technology is the ability to dominate in the information sphere. As one pilot who has flown F-22, F-35, and 4th generation fighter aircraft explained, “It used to be as a fighter pilot that speed was life, and more was better. Today, information is life, and more is better. Period.”²⁷ It all comes down to understanding the battlespace to identify and circumvent threats, seek opportunities

to best net mission goals, and cooperate with other assets in the region to harness collaborative advantages that are more powerful than any individual aircraft’s onboard capabilities. In the words of another F-22 pilot:

A complete, comprehensive information picture of the adversary threat environment is what we need to best position ourselves to fight and win. 5th generation’s sensors, processing power, and fusion with other assets in the region does that. ...It helps the pilot identify points of weakness in the adversary system by analyzing it as an integrated ecosystem.²⁸

Although legacy aircraft also feature a range of sensors and processing capability, these systems are generally federated and present stove-piped information streams to their pilots, who must try to interpret and fuse the streams into mental pictures of the battlespace. This takes tremendous amounts of training and continual practice. Even then, there can be wide variances between the amount of decision-quality information a given pilot may be able to process and use in demanding combat scenarios. While upgraded 4th generation aircraft like the F-15EX or late block F-16s feature better sensors and fused processing power than their older predecessors, the lack of stealth greatly limits when and where they can fly. The interrelated, integrated strengths of 5th generation fighter aircraft give them crucial combat capability advantages.

To assess the relative cost-per-effect of 4th generation versus 5th generation fighter aircraft capability, it is important to compare how they are now operationally employed. While few aircraft operate alone in contested threat environments, 5th

It all comes down to understanding the battlespace to identify and circumvent threats, seek opportunities to best net mission goals, and cooperate with other assets in the region to harness collaborative advantages that are more powerful than any individual aircraft’s onboard capabilities.

generation aircraft generally fly in much smaller groups because they require far less support from systems that degrade enemy defenses. Today, even the most capable, late-generation non-stealth combat aircraft require relatively large supporting packages of fighters that provide air superiority, adversary defense-suppression aircraft, and radar jamming systems. These force packages can often exceed two dozen aircraft. When considering the acquisition cost for this array of aircraft, as well as the cost of aircrew and associated maintainers, logistical demands, basing requirements, and basic consumables like fuel, this is a tremendously expensive force structure proposition. Even with this amount of support, legacy aircraft are still more vulnerable than their 5th generation counterparts, so attrition factors need to be considered. In comparison, a handful of F-22s, F-35s, or B-21s that are capable of accomplishing the same missions with far less support cost less to procure, sustain, and employ—considering personnel, logistics, and attrition reserve.

To be more specific, interesting data has recently emerged that will support more accurate cost comparisons between the Air Force's future F-15EX "4th generation-plus" fighter and the F-35. While the details surrounding the F-15EX's specific unit cost are not entirely clear, it is known that the initial tranche of aircraft will cost roughly \$98.3 million, with follow-on tails hopefully costing closer to \$80 million per unit.²⁹ The F-35, the only 5th generation fighter currently in production and roughly comparable in terms of mission focus to the F-15EX, is seeing its price—contractually defined—fall from \$89.2 million for production Lot 11 to \$77.9 million by Lot 14. The F-35, despite its far more advanced stealth design and information dominance strengths, is slated to cost about the same as or even less than the F-15EX.

Baselining Comparative Assessments

With the Air Force slated to buy both the F-35 5th generation fighter and the F-15EX advanced 4th generation fighter in the 2020s, cost comparisons will undoubtedly be made between the two airframes. An accurate assessment will require a cost-per-effect approach because the technological attributes of the two aircraft will demand different operational concepts of employment—much like the F-117s of Desert Storm versus the legacy non-stealth aircraft.

Similarly, cost-per-effect value assessment must also be applied when the B-21 is fielded. Next-generation aircraft are defined by game-changing technologies. The analysis must reflect such realities.

A comparison of flying hour costs tells a similar story. While the F-35A currently has higher operating costs than the anticipated F-15EX—\$35 thousand per flying hour versus a projected \$27 thousand respectively—cost-per-effect assessments greatly favor the F-35A. The long-touted "stealth cost penalty" is really a small percentage of what it used to be for earlier generation stealth aircraft. Today, the more significant cost drivers are associated with a combat aircraft's sensors, processing power, and data links. For instance, if one inflates the unit cost of F-15Es procured in 1998 to 2020 dollars, it comes in around \$50 million per jet.³⁰ The difference between the F-15E at \$50 million versus an F-15EX at \$80 million is largely the result of the latter's upgraded sensors, processing power, and data fusion capabilities. If this is the case, it makes far more sense to integrate these capabilities into an airframe that has a much greater chance of executing a mission and returning home safely thanks to its stealth attributes.

As for the \$1 trillion figure cited in the *New York Times* for the F-35 program, that

number is a projection of the entire cost to procure all F-35s for the Air Force, Navy, and Marine Corps, along with all their associated sustainment costs for the next 60 years—including inflation. It would be an understatement to say that projections of this magnitude are more hyperbole than an accurate cost picture. However, the more important question that should be asked is: what are the real costs of operating the F-15EX over the same period of time, including the expense of additional support aircraft and other operational demands compared to the F-35? A cost-per-effect model will prove the cost of the F-15EX will be far higher, and its operational utility to future commanders will be far lower.

Efficiencies Do Matter: Range and Payload

When it comes to assessing the relative value afforded by aircraft in a cost-per-effect construct, it is important to recognize that while airframes that have long range and sizable payload capacity may cost more to buy, they often afford distinct operational efficiencies. This is especially true for operations over vast distance, when missions demand significant loiter time in the battlespace, or where there are a high number of targets.

The drivers behind this are straightforward. First, aircraft with large payload capacity can carry more weapons in one sortie than several smaller combat aircraft. For example, one B-1 can carry 84 500-pound unguided weapons, 24 AGM-154 Joint Standoff Weapons (JSOW), 24 AGM-158 Joint Air-to-Surface Standoff Munitions (JASSM) and 15 GPS-guided Joint Direct Attack Munitions (JDAM). A single B-2 can carry 80 independently targeted 500-pound class GBU-38 JDAMs, and an Air Force B-52H can carry 20 2,000-pound class JDAMs—with further potential modifications increasing carriage capacity

in all three bomber types. While payload specifics for the new B-21 are classified, the total will be substantial.³¹ It would require 12 fighters like the F-16 or F/A-18 to carry the same 24 2,000-pound GBU-31 JDAMs that can be delivered by a single B-1B bomber sortie. The ratio holds true for smaller types of munitions. Twelve aircraft with fighter-sized payload capacity could carry up to 96 250-pound GBU 29 Small Diameter Bombs (SDB), which is equivalent to the number of SDBs that one B-1 can carry into combat.³²

In the real-world combat conditions of the opening stages of Operation Inherent Resolve (OIR)—the operations against the Islamic State—between August 8 and 20, 2014, the Navy flew 30 strikes with a nominal load of two 500-pound PGMs off the deck of the aircraft carrier USS George H.W. Bush (CVN-77).³³ A single B-1 with unguided munitions or a single B-2 with guided munitions could have delivered greater effects in a single sortie in a single day. Putting aside that aircraft carriers conduct a variety of missions other than strike, a cost-per-effect analysis of this mission shows a significant cost-effectiveness advantage for bombers over aircraft carriers.

The cost-effectiveness of bombers is dramatic when put in the context of effects accomplished relative to all the other means of target attack. B-2s flew just 3 percent of the strike sorties during Operation Allied Force over Kosovo and Serbia but hit 33 percent of all the targets. B-1s flew 2 percent of the sorties during Operation Allied Force but delivered 20 percent of the bomb tonnage. Similarly, U.S. bombers flew 20 percent of the sorties during the opening phases of Operation Enduring Freedom over Afghanistan yet dropped 76 percent of the munition tonnage.³⁴

Moreover, by concentrating this much firepower on one aircraft, commanders can project a significant amount of precision force

in rapid, concurrent fashion. This provides the advantage of compressing operational timelines, which likewise reduces time and options available for an enemy to respond. It also yields basic pragmatic efficiency because one aircraft does what it would take multiple smaller types to accomplish.

If analysts compare rough cost per flying hour expenses for two different types of strike sorties—one bomber versus 12 fighters, for example—the cost to operate the latter option on a per-hour basis is 371 percent higher. It is a simple matter of efficiency—12 engines versus four consuming fuel, 12 pilots versus four aircrew in the bomber, and associated sustainment costs for 12 aircraft versus one.³⁵ This does not even factor variables involved with facilitating long-range mission support, nor the operating and personnel costs of an entire aircraft carrier battle group to host those fighters.

Bombers can also fly extensive distances without refueling—6,000 miles for the B-2; 7,500 for the B-1; and 8,800 for the B-52H—thanks to their massive internal fuel capacity.³⁶ In comparison, fighters like the F-16C, F-15E, and F-18E/F have an unrefueled range of approximately 1,000 miles, depending on their flight profiles and weapon loads.³⁷ While reach can be extended with in-flight refueling, this drives up cost, operational complexity, and the risk of mission loss, especially if aerial refueling tankers must operate close to enemy defenses.

A prime example of this increased mission complexity and cost occurred in the opening days of Operation Enduring Freedom when theater airbase availability limitations required F-15Es to fly from Kuwait to strike targets in Afghanistan. In an incredibly impressive display of airmanship, four F-15Es each carrying nine 500-pound GBU-12s, two AIM-9Ms, and

two AIM-120Cs flew a 15.5-hour mission from Kuwait to Afghanistan and back, of which 9 hours were spent over the target area.³⁸ Each of the F-15Es had to air refuel 12 times. Two B-1s could have executed a similar mission carrying 48 GBU-31 2,000-pound JDAMs with the support of four to six aerial refuelings.³⁹ Twelve more bombs on target by two fewer aircraft with half the aerial refueling requirement is a more efficient operation by anyone's calculus.

Furthermore, aircraft range and payload are increasingly important attributes for a future Air Force that is sized and shaped to operate from an array of bases spread across the vast distances of the Indo-Pacific region. The shift toward planning for great power conflict will also increase the Air Force's need to efficiently amortize its aerial refueling tanker assets and prepare to attack Chinese or Russian target sets that are far larger than the target sets of Operation Desert Storm (Iraq 1991), Operation Enduring Freedom (Afghanistan 2001–2014), and Operation Iraqi Freedom (Iraq 2003–2011).

As far as cost is concerned, this is a conversation that must be put into operational context since a lot more is at play than the acquisition of new weapons systems. Mission results and the fiscal bottom line are not enhanced by buying systems with seemingly lower up-front procurement costs only to have to pay far higher costs in future real-world operations for less combat potential per jet. Nor is it wise to compare peacetime operations and support costs for capability options without also comparing warfighting mission attributes and costs. Analyses without mission value context happen all too frequently, often accompanied by sweeping assertions. As one defense analyst stated in a recent article on the cost of the

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B-1 bomber force, “The Air Force can’t get the ‘Bones’ [B-1s] to the boneyard fast enough because the maintenance costs of just keeping them flying are ruinous.”⁴⁰ Defense decisionmakers should ask: ruinous compared to what? If the answer is smaller payload aircraft, then decisionmakers should consider the need to use a larger number of them to match the payload capacity of bombers, plus more aerial refueling tankers, and more logistical support. These cost-per-effect analyses should also inform the overarching size of the future bomber force. Bombers have often been subject to the budget axe while investments continue for aircraft with higher cost-per-effect outcomes. Given that the Air Force’s Global Strike Command has seen COCOM requests for bombers increase by 1,100 percent over the last 5 years, the attributes of long operational ranges and large payload capacity appear to matter greatly.⁴¹

Implementing Cost-per-Effect Assessments: Potential to Improve DOD’s Requirements Development Process

The Department of Defense acquires military capabilities through a three-fold process. Requirements that will yield future systems are derived through the “Joint Capabilities Integration and Development System” (JCIDS)—a process whereby strategy-driven requirements are tied to pragmatic solutions. Once a path forward is defined, the systems are procured through the acquisition enterprise. The budget process pays for the given solutions. These functions are best viewed as a Venn diagram with periods of overlap depending on where an initiative is within the cycle. A cost-per-

effect approach to informing procurement decisions should occur during the JCIDS phase of acquisition via key performance parameters—the stated desired attributes of a given system.

The JCIDS process begins with a capabilities-based assessment whereby procurement officials evaluate mission demands, desired capabilities, current capability gaps, and alternate solutions. This ultimately yields an Initial Capabilities Document (ICD), which scopes the type of solution that could best meet desired outcomes. From there, leaders can: 1) agree with the ICD document and press for a material solution; 2) seek to address the shortcomings through improved processes; or 3) do nothing and make the most of existing options. Presuming a material option is the favored course of action, leaders then devise a Capability Development Document (CDD), which focuses on a set of requirements via KPPs; this is when cost-per-effect matters the most. This involves evaluating how a system is expected to perform in given scenarios based upon specific factors:

- Number of effects that could be generated on a mission and supporting elements necessary for facilitation, such as protective escort aircraft and aerial refueling
- Ability to team with other battlespace assets to yield collaborative effects
- Expected combat casualty rates
- Basing support requirements not just for the aircraft itself but for the broader supporting enterprise, such as escort fighters, tankers, aircraft carriers, support ships, personnel, logistics requirements, etc.

This sort of evaluation would force strengths and weaknesses to emerge based upon mission demands, thereby allowing leaders to make informed decisions based on desired attributes. As Dr. William LaPlante explained:

Failing to adopt a cost-per-effect methodology will see DOD and the services potentially invest money less effectively. An upfront analysis, much like was done at the front end of what became the B-21, is crucial in driving effective, efficient superior choices from the beginning of a program. Given the reality of tight budgets, and the need for “engage on remote” effects and warfighting, we need to adopt this approach.⁴²

The bottom line, cost-per-effect enables the U.S. military to maximize desired mission objectives in the most effective, efficient manner possible.

Cost-per-Effect Imperative in the Context of an Air Force Under Stress _____

Using cost-per-effect as a metric to determine the most prudent investment choices for the DOD is even more important considering the magnitude of the Air Force’s shortfalls in capacity and balanced capability. Air Force leaders are rightfully concerned about the size of the force in relation to demand. The service’s aircraft inventory is now the smallest, oldest air fleet since the branch’s 1947 founding. As Air Force Deputy Chief of Staff for Operations Lt Gen Mark Kelly explained:

Many people envision today’s Air Force as the one that went to Desert Storm—a force that featured 134 Fighter Squadrons. The reality

is that we only have 56 now and I can point to comparative force reductions in nearly every other mission area. Look at the B-1 fleet—it is down because we literally flew it beyond sustainment capacity. That means the four B-52 Squadrons are doing the work previously executed by the three B-1 squadrons and the load these B-52 units were already carrying. That’s seven squadrons’ worth of work balanced on four. None of the other services and none of our allies have bombers, so it is important we keep this uniquely USAF capability combat ready. The list goes on throughout the rest of our mission areas.⁴³

Years of hard use, anemic modernization funding, and budget-driven divestitures have caught up with the Air Force, and it is time to reset both its mix of capabilities and upgrade its capacity.

The pressure Air Force commanders face to meet combatant commanders’ force structure demands is pronounced. The service would run out of aircraft for operations that fall well short of the scenarios outlined in the *National Defense Strategy*, like engaging in a major conflict with a peer aggressor plus meeting other critical operational commitments concurrently. As Air Force Lt Gen Kelly explained:

Consider how a scenario would play out today in the case of an escalating European peer threat. The Air Force would hear from General O’Shaughnessy at NORTHCOM, requesting that we take airspace control level to a higher readiness state. That would obligate fighters, AWACS, and tankers to the homeland defense mission. Added

to that, a peer threat would see Admiral Richard of STRATCOM seek to put the bomber force at a higher state of alert, which also obligates tankers. Next, we would see General Raymond advising that he is reorienting the space architecture to support EUCOM. General Wolters would then call to expedite the “halt force” needed for a peer fight in Europe. We would also hear from General Clarke from SOCOM asking for conventional support to Special Forces in support of EUCOM. General Abrams would call to ensure there is enough combat power to check North Korea’s cycle of provocation so we could deter against opportunistic adventurism at a time when the U.S. is focused on Europe. A similar set of calls would come from General McKenzie regarding the threat posed by Iran.

After the fourth conversation—the request from General Wolters—we are out of capacity. This is even with the Air National Guard and Air Force Reserve fully mobilized. Not only does this see us without the resources to execute this one scenario, but I would have done little to check potential action by the Chinese. Nor have we factored in what it would take to sustain combat operations in the first scenario I needed to start backfilling for attrition and combat losses. The numbers simply are not there.⁴⁴

This illustrative crisis scenario is but one of many that could occur in the future. The Air Force needs to balance its capabilities and force capacity for competition and to deter future conflict

with China and Russia; check aggression from regional actors like Iran and North Korea; and meet threats from non-state actors like ISIS and Al Qaeda. Not only do the scope and scale of these threats present unique and highly consequential challenges on an individual basis, but their concurrency also radically increases the challenges faced by U.S. combatant commands (COCOMs) and the Air Force. As General Kelly explained, the Air Force is now simply too small to realistically meet these demands. Nor does it have a balanced set of capabilities—attributes like 5th generation systems are in too short supply.

The magnitude of these challenges was a primary driver in the Air Force’s 2018 call for a future force of 386 operational squadrons, a goal that is called “The Air Force We Need.” This objective force represents modest growth from the service’s present 312 operational squadrons, given the magnitude of the threat to America’s security. As then-Air Force Secretary Wilson explained, “We must see the world as it is. That is why the National Defense Strategy explicitly recognizes that we have returned to an era of great power competitions. We must prepare.”⁴⁵ Secretary of the Air Force Barbara Barrett, Wilson’s successor, reaffirmed her commitment to this goal in her confirmation hearing, citing that “a great deal of effort was put into an analysis of what is ‘The Air Force We Need’ by my predecessor. I would think that’s not something that’s destined for the shelf, but instead destined for implementation... so that we can have the force structure that we need to pursue and achieve the mission.”⁴⁶ This force structure growth does not represent an investment in surplus “insurance policy” capacity; it is needed to execute real-world missions at a moderate level of risk today and in the future to meet *today’s* national defense strategy.

Air Force Resourcing Trends

The Air Force is not funded equally with the other services. It absorbed the largest cuts to its annual budgets between the end of the Cold War and 9/11 as compared to the other branches. From FY 2008 to FY 2011, the Air Force received its lowest share of the defense budget since the Eisenhower administration. FY 2013 marked the Air Force's third lowest level of new aircraft funding in the service's history and the lowest level ever as a percentage (4.3 percent) of its topline budget.

The FY 2020 President's Budget allocated 19 percent to the Air Force. Of this amount, \$39 billion transferred to accounts largely residing in the intelligence community, not to actual Department of the Air Force functions. This amount could procure over 400 new 5th generation F-35As.

For more information, read [Mark Gunzinger and Carl Rehberg, *Moving Toward the Air Force We Need? Assessing Air Force Budget Trends*](#).

This is why leaders should exercise great concern that 80 percent of the fighter aircraft in the current Air Force inventory lack the increasingly essential 5th generation attributes of stealth; advanced electronic warfare technologies; and the ability to gather data, process and fuse it, share it across robust data links, and collaborate via a broader combat cloud command and control (C2) architecture. Nor are circumstances any better when it comes to the bomber inventory, with just 20 B-2s representing the nation's entire stealth bomber capacity. The Air Force needs to reshape with the right balance of essential attributes and increase in size to meet modern operational demands.

Air Force leaders are not alone in recognizing these challenges. The 2018 National Defense Strategy Commission concluded that "U.S. military superiority is no longer assured and the implications for American interests and American security are severe."⁴⁷ To help gain the necessary tools to

meet these challenges, the commissioners recommended "that Congress increase the base defense budget at an average rate of 3 to 5 percent above inflation through the Future Years Defense Program (FYDP) and perhaps beyond."⁴⁸ Three to five percent growth year-by-year in the Air Force's budget would be an increase of about \$8 billion per year over a 10-year period. Whether that will happen in a post-COVID-19 era of burgeoning deficits is highly unlikely. That said, the point remains exceedingly valid and only emphasizes the necessity of making each defense dollar procure and sustain the most prudent set of capabilities to maximize desired outcomes.

Even if topline defense budget increases are not possible, cost-per-effect assessment would clearly highlight areas where internal monetary shifts between programs will allow the prioritization of the smartest investment priorities.

Even if topline defense budget increases are not possible, cost-per-effect assessment would clearly highlight areas where internal monetary shifts between programs will allow the prioritization of the smartest investment priorities.

Such assessments must also happen across services and must focus on mission effects, not parochial service control absent meaningful results. For example, is the Army's pursuit of a new cannon with a 1,000-mile range really the best use of resources when strike aircraft, remotely piloted aircraft, and bombers net the same mission results more effectively, survivably, and efficiently? Those are precisely the kinds of assessments that need to occur when mission demand will be on the rise and available dollars on the decline.

Each DOD mission area should conduct a cost-per-effect assessment approach. They must find the right balance between the volume of resources required to execute given missions and achieving the most efficient, effective options for doing so. For example, to assess the cost-per-effect potential of two strike aircraft alternatives, key questions for analysis should include:

- For each of the two options, how many of the candidate strike aircraft would be required to execute a given task such as successfully penetrating contested airspace and striking a target?
- Which option would require a larger package of supporting aircraft and other capabilities to ensure they can successfully perform their mission?
- What are the total costs for each option to achieve this notional mission, including but not limited to the costs of operating the actual strike aircraft, weapons expended, operating costs of their required supporting capabilities, sustainment considerations, logistic, personnel, and basing requirements?

Combat aircraft are purchased once and operated for decades; the B-52 is on track for the century mark. The value they deliver on a recurring basis is tied to cost; however, it is simplistic to think that there are “silver bullet” solutions that will yield favorable cost-per-effect advantages across all spectrums of the threat environment—from non-state actors to mid-tier opponents and peer adversaries. As with all aspects of DOD expenditures, the real answer comes down to context, including the threat environment, mission goals, and the scope

of the operating theater. It is one thing to execute a limited number of strikes against a low-tech adversary and quite another to launch a theater-sized air campaign against a highly advanced foe with potentially tens of thousands of aim points that U.S. aircraft must strike as rapidly and precisely as possible.

Conclusion

Airmen have long sought to harness new strategies, operational concepts, and technologies to become more effective at winning America’s wars. Airmen flying over the bloody, stalemated trenches in World War I realized that the third dimension of the air empowered them to strike enemy centers of gravity such as command and control centers, factories, and supply depots whose destruction would have an outsized impact on achieving critical campaign objectives. The very airmen who pioneered these concepts in World War I served as senior air commanders in World War II. Using the best technology available at the time, they executed a strategic air campaign of immense proportions against Axis targets in both Europe and the Pacific.

While airpower technologies and operational concepts evolved over the course of World War II, airmen realized the theory of strategic attack from the air was valid. Over the ensuing decades, they remained committed to investing in mission tools that would better meet air combat requirements. In 1991, their success was dramatically demonstrated by the F-117 stealth fighters that struck across the breadth and depth of Iraq during Operation Desert Storm with disproportionate effects relative to non-stealth aircraft. Thanks to the protections afforded by stealth technology, precision weapons, and an innovative effects-based targeting strategy, these aircraft did not require fighter escort.⁴⁹

A Vignette from the WWII Allied Bombing Campaign in Europe

The resources needed to hit a single target during the Allied bombing campaign in Europe were staggering, given the lack of precision strike technology and the lethality of Germany's air defenses. A prime example of the required scale of effort occurred on January 28, 1944, when 863 B-17s and B-24s of the U.S. 8th Air Force launched from the United Kingdom and released 1,895 tons of bombs against a target in Frankfurt Germany. Twenty-nine of the bombers failed to return from the mission, and an additional 135 were hit by enemy fire, of which five were so damaged they never flew again. 353 airmen were listed as either killed, wounded, or captured during the raid. Added to this, 632 fighter aircraft flew as part of the total bomber strike package, of which 15 were shot down. On average only 20 percent of bombs struck within 1,000 feet of their intended targets during daylight bombing operations, so unfortunately this massive strike operation saw 80 percent of its strength effectively negated due to technological limitations and enemy defenses.

This progress is a dramatic illustration of the benefits of measuring the relative value of an aircraft in the context of meeting real-world mission demands. With both sums normalized for 2019 dollars, the F-117, at a unit cost of \$50,560,960, was dramatically more expensive to acquire than the B-17 with a unit cost of \$3,383,450.⁵⁰ However, in the example cited in the vignette above, 863 World War II-era bombers were needed to eliminate one target, whereas only 20 F-117s were used to strike 28 separate targets in just one hour of a conflict scarcely 50 years later. Using a simple cost-per-effect model, it cost roughly \$36 million for an F-117 to strike a target, far less than \$292 million per target for the World War II bombers. And yet, this latter figure wholly ignores the cost

of the bombers' fighter escorts; the fact that each World War II bomber was crewed by ten airmen versus a single pilot for an F-117; and the relative cost of spare parts, fuel, logistical support, and basing infrastructure. More importantly, the comparison does not consider the far more important human costs involved in the loss of so many bombers.

While two starkly different generations of aircraft, this example illustrates that advances in technology when applied to meeting mission needs can yield incredible operational benefits and efficiencies. Given the high average age of much of the Air Force's force structure, the capability spread between its legacy and newer 5th generation aircraft is stark. Unit cost pales as a means to effectively measure the difference in overall cost of attaining desired effects in real-world operations. More accurate cost assessments should focus on the full slate of tools required to execute a mission, not individual cost figures that lack important context. This is why including cost-per-effect as a key performance parameter within DOD's JCIDS requirements process is absolutely necessary to shape an effective, efficient future force.

To this point, Congress should consider including language in the National Defense Authorization Bill requiring DOD to devise new measures to assess cost-per-effect for key mission areas and then implement such evaluations in the future force development process. Such measures should be domain-, service-, and platform-agnostic, and instead focus on how best to achieve mission goals in future operations.

While this report focuses on the higher end of the operating spectrum, it is also important to recognize that the future U.S. military should not be designed around a "one size fits all" mix of capabilities. While stealth, advanced electronic warfare systems, cyber options, range, and payload are increasingly

"Nobody has ever won a war by trying to run it on the cheap. Nothing is so expensive as losing a war by saving money. If you want the cheapest possible Air Force today, it is very easy to standardize on a whole lot of aircraft that will be of no use when the war comes."

Sir Frederick Handley Page

important capabilities, there are still missions where lower technology and lesser capable systems have enduring value. For example, the MQ-9 Reaper should continue to play a vital role in countering terrorism globally. The aircraft is incredibly adept at tracking targets of interest and seeking the most opportune times to employ force.⁵¹ At the end of the day, the U.S. must balance the future force. What does not work is ratcheting up budget pressure so high that DOD leaders have no recourse other than retiring core capability and capacity in a whack-a-mole game of budgeting.

Nor is this a totally bad news story. According to Dr. William LaPlante, who was a key leader involved with the selection of the B-21 as the Air Force's new bomber, cost-per-effect type analysis formed a key part of his team's thinking:

The B-21 program benefited from a front-end effects-based value and cost assessment across the long-range strike "family of systems"—to include kinetic, non-kinetic, ISR, comms, etc. In the wake of canceling the next-generation bomber program, Secretary Gates ordered a capability analysis that evaluated various long-range strike options and scenarios based upon a capability-cost methodology. This involved looking at a wide variety of long-range strike options such as arsenal plane, surface-based stand-off missiles, prompt global strike concepts, and various air-delivered options, including manned and unmanned. Analysis showed that the penetrating long-

*range strike aircraft, which became the essential requirements of what is now the B-21 bomber, could deliver desired effects at lowest cost given specified mission parameters. But this was all derived from a holistic long-range strike family of systems analysis—with other capabilities also specified beyond the B-21.*⁵²

This sort of approach should be applauded and needs to be further encouraged throughout the DOD acquisition enterprise to ensure it is being applied to a broader swath of programs.

Consider the advice of Sir Frederick Handley Page, a British aviation pioneer: "Nobody has ever won a war by trying to run it on the cheap. Nothing is so expensive as losing a war by saving money. If you want the cheapest possible Air Force today, it is very easy to standardize on a whole lot of aircraft that will be of no use when the war comes." The sanctuary that America enjoyed in the decades after the Cold War is over. The threats posed by Russia, China, and a host of other nations like Iran and North Korea are very real. As Senate Armed Services Committee Chairman Senator Jim Inhofe recently concluded, "I really believe we're in the most dangerous situation we've been in in this world in my lifetime."⁵³

Meeting those threats demands accurately aligning DOD's weapon procurements with tactics, operational concepts, and warfighting strategy. It should not focus unduly on what appears to offer the cheapest price tag or lowest individual hourly operating cost. Such assessments simply miss the point of what drives real cost. Cost-per-effect must be harnessed as a tool by the Air Force, Department of Defense, OMB, and Congress as they seek to ensure tomorrow's military personnel will be best equipped to meet the nation's security requirements. 🌟

Endnotes

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