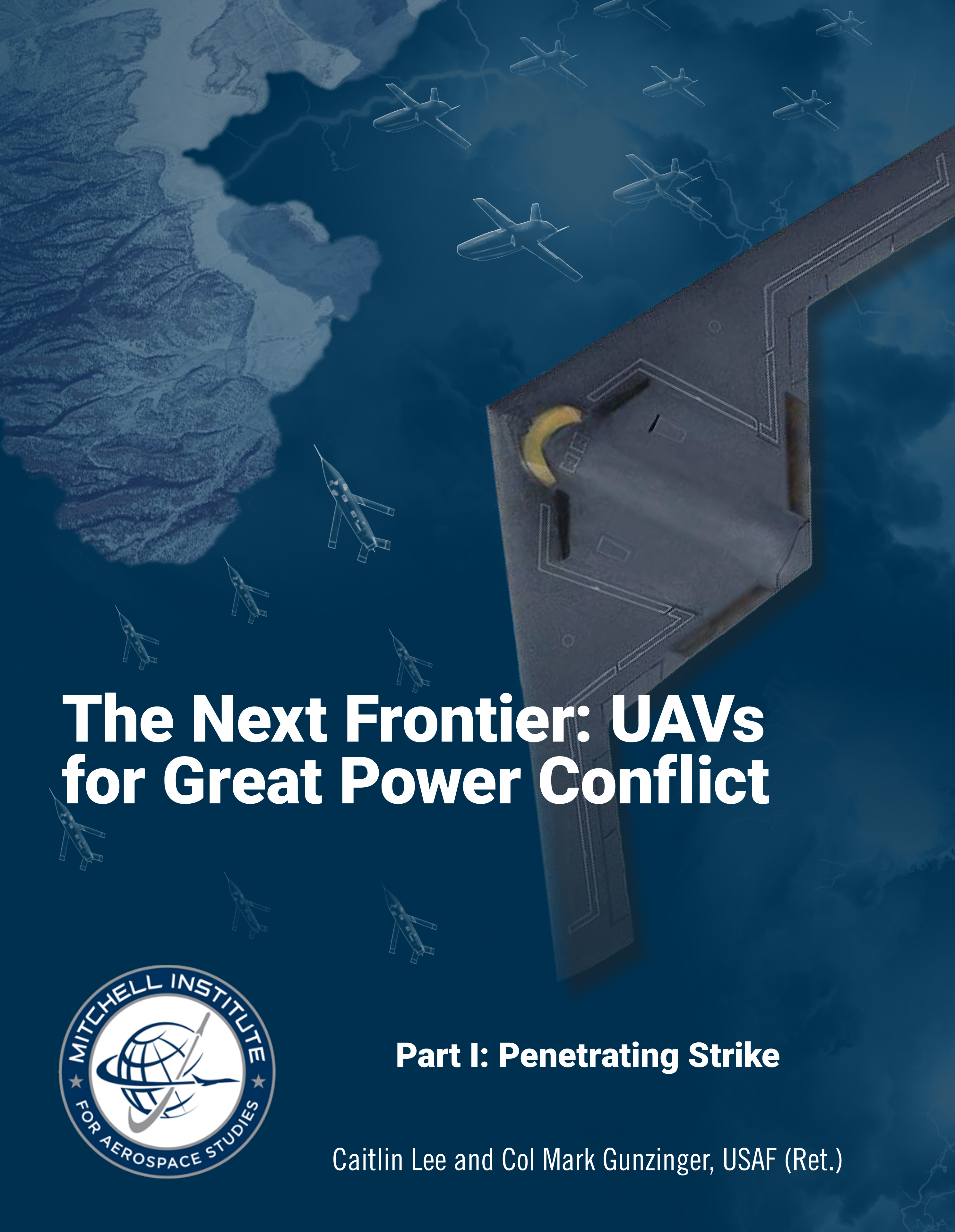

The Next Frontier: UAVs for Great Power Conflict

MITCHELL INSTITUTE FOR AEROSPACE STUDIES

Part I: Penetrating Strike

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THE NEXT FRONTIER: UAVS FOR GREAT POWER CONFLICT
PART 1: PENETRATING STRIKE

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The Mitchell Institute for Aerospace Studies

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About the Mitchell Institute for Aerospace Studies

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Foreword

In March 2022, the Mitchell Institute for Aerospace Studies established the Center for Uninhabited Aerial Vehicles (UAV) and Autonomy Studies (MI-UAS) to inform and elevate debate on an emerging set of technologies that are increasingly critical to deterring and, if necessary, defeating great power aggression. Offensive and defensive operations during Russia's invasion of Ukraine have confirmed that UAVs will have an important role in modern conflict. New technologies in conjunction with autonomy have the potential to shift battle outcomes and, depending on the situation, may even alter the strategic balance.

To better understand these emerging UAV technologies and concepts for their employment, MI-UAS launched a project called "UAVs in Great Power Conflict," consisting of a series of two papers authored by MI-UAS director Caitlin Lee and Mitchell Institute's director of future concepts and capability assessments, Mark Gunzinger. In this first paper, they examine the opportunities and challenges facing the U.S. Air Force as it races to field a new generation of UAVs it calls autonomous collaborative platforms (ACPs). Their analysis centers on a near-term postulated Chinese invasion of Taiwan and examines how ACPs might provide operational advantages to U.S. forces engaged in long-range penetrating strike missions. A second paper, scheduled for release in 2023, will continue this effort by exploring issues surrounding the employment of ACPs to support counterair missions and achieve air superiority in a great power conflict.

More than twenty years after the first MQ-1 Predator shot a missile against a real-world target in Afghanistan, the Air Force is now approaching the next frontier of UAV innovation. Service leaders are reconsidering nearly every aspect of UAV capability and concept development. It is an exciting time, and one that is filled with both risks and opportunities that are not yet fully understood. Rapidly changing technologies and the emerging strategic environment present a fundamentally different set of challenges than the threats the United States confronted in the past. The UAVs in Great Power Conflict series represents a first look at the MI-UAS approach to analyzing these challenges with objective, open-source analysis designed to inform critical technology, policy, and budget decisions that will shape the future of aerospace power for decades to come.

Lt Gen David A. Deptula, USAF (Ret.)
Dean, The Mitchell Institute for Aerospace Studies

Executive Summary

Only a few years ago, the idea of the U.S. Air Force operating uninhabited aerial vehicles (UAV) with artificial intelligence (AI) in highly contested airspace seemed to many like science fiction.[1] U.S. forces deftly employed UAVs in the benign airspace of Iraq and Afghanistan in ways that revolutionized high-value targeting, close air support, and other missions, but there was little concern about an adversary shooting back.[2] Now fast-forward to 2022, and the Air Force is once again looking to UAVs to improve its combat effectiveness, but this time the threat comes from China, a peer challenger that is approaching, or in some cases surpassing, the level of U.S. conventional combat power. Air Force leaders are making a big bet on a next generation of UAV technologies—which it collectively refers to as autonomous collaborative platforms (ACP)—to help restore its conventional overmatch vis-a-vis China, now the pacing threat around which the U.S. military is prioritizing its capabilities.[3]

A confluence of factors, including the strategic threat posed by China, rapid technological advances, and growing evidence that ACPs can improve operational outcomes, have created a groundswell of support across the Air Force, the Department of Defense (DOD), and industry, to move ACPs into the battlespace quickly.[4] Since the end of the Cold War, budget pressure has forced the Air Force and other services to shed capacity and readiness to a point that they must now largely rely on smaller numbers of advanced systems and a shrinking overseas posture.[5] Meanwhile, China is approaching conventional parity with U.S. forces, building an array of modern military technologies and a low-cost missile force explicitly designed to keep U.S. and allied forces at arm's reach.[6] To turn the tables on China, the Air Force is looking for low-cost ways to offset its significant capability and capacity gaps. Betting they can harness rapid technological advances, particularly in AI and aircraft design and manufacturing, Air Force leaders plan to field large numbers of ACPs as part of the solution to their force structure shortfalls.[7]

Key Terminology

This report uses uninhabited aerial vehicle (UAV) to describe aircraft that can operate without a human onboard. Autonomous collaborative platforms (ACP) meet this definition and refer to next-generation UAV technologies the Air Force is developing for future conflict. ACPs are distinct from current-generation UAVs in that the Air Force envisions using them *in conjunction* with other combat aircraft to perform a wide range of missions *in contested operational environments.*

This paper also addresses loitering munitions, which technically also meet the definition of a UAV, but these systems are purpose-built to be expendable weapons. They are also distinct from traditional munitions like cruise missiles because they typically can loiter in a target area for longer periods of time.

This report examines the roles, missions, and capabilities that ACPs might provide to enhance the combat credibility of the Air Force, as well as the opportunities and challenges inherent to their rapid development and fielding. It focuses on the role of ACPs in penetrating strike missions because they are critical to meeting the demands of the *2022 National Defense Strategy* (2022 NDS), which calls on the U.S. military to deny China and Russia the opportunity to rapidly seize territory.[8] Penetrating strikes involve the employment of advanced bombers deep within adversary airspace and, as such, can play a key role in blunting and halting mobile adversary invasion forces in the early days of a conflict. But these missions require a complex array of strike, electronic warfare, counterair, and other capabilities, all of which could place a significant strain on the Air Force during a great power conflict. By collaborating with advanced bombers to provide some of these capabilities, large numbers of low-cost ACPs may improve mission effectiveness and lower operational risks.

Air Force leaders recognize this potential and have made it a top priority to pair ACPs with inhabited aircraft including fighters, bombers, and even mobility forces. As they prepare to request substantial resources from Congress to begin acquiring ACPs in fiscal year 2024, these leaders must communicate to lawmakers, other Department of Defense (DOD) leaders, industry, and the American public exactly how ACPs will contribute to U.S. deterrence and warfighting capabilities while painting a realistic picture of the opportunities and challenges that lay ahead. Mitchell Institute conducted an unclassified workshop with operators, scientists, and engineers from the Air Force and defense industry to examine these issues. To ground the analysis, we asked workshop experts to identify how ACP operating concepts and technologies might mitigate risks to advanced bombers and improve the effectiveness of penetrating strike missions in a campaign to defeat a Chinese invasion of Taiwan, a pacing scenario for DOD force planning.[9]

Expert Insights

A central insight developed during this project is that **large numbers of relatively low-cost ACPs could help offset serious force structure shortfalls that now threaten the Air Force's ability to meet combatant commander demands in the era of great power competition.** In the workshop, experts developed concepts for employing the varying ACP types in ways that would complicate adversary targeting decisions, forcing the adversary to expend significant time and resources to reduce that uncertainty. Experts did not see ACPs as a substitute for the deterrence and warfighting capabilities of inhabited stealth bombers and fighters.[10] However, they concluded that, if fielded quickly, at low cost, and in large numbers, ACPs could help mitigate significant gaps in the Air Force's ability to conduct long-range penetrating strikes to deny large-scale aggression.

Air Force and industry experts were particularly interested in using ACPs to mitigate both capability and capacity gaps in counterair, a portfolio of missions essential to the success of penetrating strike missions in highly contested environments. They also prioritized using ACPs for intelligence, surveillance, and reconnaissance (ISR). In this role, they could free up advanced bombers and strike fighters to focus on their primary mission—delivering weapons on targets. ACPs in ISR roles also could reduce the need for stealth bombers' sensors to emit; this is important because bomber crews seek to avoid emissions in contested environments to minimize probability of detection.

Other benefits associated with lower-cost, modestly capable ACPs include the potential to surge their production in wartime and a higher tolerance for operational losses. To this end, experts preferred ACPs to be attritable or expendable; the Air Force would have a relatively high tolerance for losing them because their out-of-pocket costs would be relatively low and mission commanders would see their loss as worth the operational

ACPs, Combat Credibility and the 2022 NDS

The 2022 NDS calls for the U.S. military to build a combat-credible force that will reduce a competitors' perception of the benefits of aggression relative to restraint. It calls for U.S. forces to strengthen deterrence by building up forces to support three approaches:

Denial—preventing adversaries from rapidly seizing territory

Resilience—withstanding, fighting through, and recovering from disruption

Cost imposition—imposing costs in excess of the perceived benefits of aggression

Workshop experts were interested in applying ACPs to all three of these approaches.

see 2022 NDS, p. 8.

gains. Finally, workshop experts preferred ACPs with high degrees of autonomy. They viewed autonomy as advantageous for minimizing communications in highly contested environments; creating opportunities to deploy larger numbers of ACPs while minimizing burdens on human controllers; and increasing the speed of decision-making relative to the adversary.

The experts' preferences for ACP capabilities and concepts reflected key deterrence approaches outlined in the 2022 NDS, which calls on the U.S. military to build forces not just to deny large-scale aggression, but to increase resilience and impose costs on the adversary. Large numbers of low-cost ACPs could contribute to all three of these approaches, suggesting ACPs could become a central Air Force contribution to support the objectives of the 2022 NDS.

Experts also identified several challenges associated with the introduction of ACPs into Air Force operational units. Most critically, they were uncertain about the maturity of the AI technology needed to support ACP autonomous operations, and they were unsure what "lower-cost" means for ACPs. How low-cost must ACPs be to increase warfighter tolerance for combat losses? And do traditional models for aircraft cost assessment still apply, given the Air Force's plans to adopt innovative approaches to manufacturing, aircraft operations, and maintenance that are meant to reduce costs? Finally, experts were unsure of DOD's ability to rapidly expand and diversify a production base for ACPs in a crisis, although they saw that function as essential for the Air Force to bring sufficient mass to the fight throughout a protracted conflict.

Recommendations for the Air Force

Despite identifying operational, technological, and budgetary challenges, experts widely agreed on the critical need to rapidly field ACPs to present a combat-credible force to combatant commanders. They assessed that the risk to penetrating strike missions could be significantly reduced by teaming ACPs with advanced bombers, and that desirable ACP design attributes such as low observability and lower-cost sensors were well within reach. Yet, quickly fielding these aircraft will require coordinated and concerted support from lawmakers, DOD leadership, and industry because of the scale of changes required to integrate them into operational units. Launching a comprehensive campaign of ACP operational experimentation will lay the foundation for their fielding and signal to key stakeholders that the Air Force is committed to the effort. To this end, the Mitchell Institute offers the following seven recommendations to the Air Force:

1. **Release an Air Force flight plan that links ACP development to the 2022 NDS, specifically, to its objectives for denying an adversary from achieving its campaign goals, improving force resiliency, and imposing costs.** The Air Force should publish an ACP flight plan to support the FY 2024 budget request that: 1) explains why ACPs are an urgent priority; and 2) provides the basis for maintaining a dynamic posture that can adjust ACP integration plans in response to changes in technology and the threat environment.
2. **Launch a comprehensive campaign of operational experimentation to create the organization, processes, industry relationships, and culture required to move prototypes into operational units.** The immediate objective of the operational experimentation campaign should be to rapidly shore up America's combat capabilities and capacity for peer conflict. In other words, get ACP "rubber on the ramp" as fast as possible by starting a new program of record; then continue experimenting to adapt the technology to warfighter needs and collect much-needed data. The longer-term goal should be to create the conditions for an effort spanning decades to evolve the way the Air Force organizes, trains, and equips its forces to the point that it becomes second nature to rapidly, continuously, and frequently field successive generations of ACPs into operational units.
3. **Prioritize modularity to enable a continuous cycle of learning, development, and production.** The Air Force should not "throw away" ACPs that are not optimized for operational demands, but seek to continuously improve their performance through AI software updates. This requires modularity: a standard receptacle in the airframe that can continuously accept new AI systems and processors as AI software evolves. The ACP development cycle should also use information and experience gained from operating lead aircraft in new UAV classes to improve the capabilities of follow-on models. And as older ACPs age, it may be possible to use them for different missions, such as adversary air, rather than relegating them to the boneyard.
4. **Complement ongoing internal analysis with unclassified workshops and wargames to refine and demonstrate ACP concepts and technologies.** The Air Force should use wargames and workshops as venues for the broader DOD community, lawmakers and their staffs, and the defense industry to improve their understanding of the potential for next-generation UAVs to improve the service's operational effectiveness in peer conflicts.
5. **Prioritize fielding ACPs with modest capabilities in large numbers; the initial fleet should include counterair capable aircraft.** Insights gleaned from the Mitchell Institute's workshop suggest the Air Force should emphasize operating concepts that involve employing large numbers of lower-cost ACPs, particularly for offensive and defensive counterair missions, to increase the lethality and survivability of long-range penetrating strikes.
6. **Determine appropriate cost assessment methods for ACPs.** DOD, Air Force, and industry experts do not agree on how to assess the cost of ACPs. Some argue that historical cost data from legacy aircraft can be used to estimate ACP costs. Others argue new approaches to aircraft design and manufacturing render that data less useful. The Air Force should use ACP operational experimentation efforts to collect new data to inform assumptions underlying ACP cost assessment.

7. **Diversify munitions for long-range penetrating strike.** The Air Force should develop ACPs within a broader force design context that considers how a new generation of munitions would increase the survivability and augment the striking power of both inhabited and uninhabited aircraft. Workshop experts identified a pressing need for smaller mid-range (40 nm to 150 nm) munitions that can be carried in large numbers internally by stealthy bombers, and loitering munitions to augment penetrating strikes against highly mobile targets.
8. **Increase Air Force funding to create a force design that combines ACPs and next-generation manned combat aircraft to conduct decisive collaborative operations.** Decades of insufficient budgets have created a high-risk Air Force that lacks the force capacity, modernized capabilities, and readiness required for a major conflict with China and other National Defense Strategy priorities. Reversing this decline requires increasing the service's budget by 3-5% for a decade or more to acquire sufficient numbers of next-generation manned combat aircraft like the B-21, NGAD, and F-35, and fund new, additive programs for ACPs that promise to yield significant advantages for America's warfighters.[11]

In summary, Mitchell Institute's research suggests that the Air Force's plans for ACPs could provide significant operational advantages to U.S. forces executing penetrating strikes, a mission that is central to denying Chinese invasion objectives in the Taiwan Strait. Developing an ACP force will require the Air Force to leverage opportunities and deal with new challenges to designing, producing, operating, and sustaining these aircraft at scale. The stakes for this force design approach are high: workshop findings suggest that ACPs can offset force structure shortfalls to ensure the Air Force can provide decisive combat power, allowing ACPs to become a centerpiece of Air Force efforts to support the 2022 NDS strategies of denial, resilience, and cost imposition.

Introduction

Air Force leaders are concerned that American airpower is losing its overmatch against China's rapidly modernizing military. This is the pacing challenge for developing the service's future force design.[12] China has invested heavily in an anti-access/area-denial (A2/AD) network of missiles, combat aircraft, command and control networks, and other advanced weapon systems that are designed to keep U.S. forces out of the Western Pacific and heavily attrit forces operating forward.[13] As the People's Liberation Army (PLA) has grown stronger over the last two decades, the U.S. military, including the Air Force, has grown weaker. The service has lost about half its forces and much of its readiness for high-end peer conflict since the Cold War, and multiple wargames and analyses now indicate the Air Force lacks the force capacity, survivability, and lethality to project decisive combat power at scale into China's A2/AD environment.[14] This threatens the DOD's ability to deter, and if necessary, defeat Chinese aggression against Taiwan or elsewhere in the Indo-Pacific as required by the 2022 NDS.[15]

To address this force structure crisis, the Air Force is making a big bet on developing and fielding a new generation of UAVs known as ACPs.[16] Air Force leaders envision using large numbers of ACPs capable of operating with fighters, bombers, and other aircraft to generate the lethality and combat mass needed to prevail in a peer conflict. As Secretary of the Air Force Frank Kendall has explained, "The expectation is that [ACPs] can be designed to be less survivable and less capable, but still bring an awful lot to the fight in a mixture that the enemy has a very hard time sorting out and dealing with."[17]

As the Air Force pursues ACPs to offset its capability and capacity gaps, it must strike a balance between two competing priorities. First, the Air Force will need to *aggressively pursue novel, and in some cases, untested approaches to UAV engineering, production, operations, and sustainment.* The service's current UAVs were not originally designed to collaboratively operate with inhabited aircraft in highly contested air environments, where air defenses and electronic warfare present constant threats.[18] Moreover, ACPs must be manufactured at the scale required for a great power conflict, which means the Air Force must be prepared to surge ACP production to compensate for combat attrition that will be more akin to losses incurred by airmen during World War II than in recent operations.[19] Given these considerations, the Air Force must incorporate some unique concepts and capabilities into ACPs across the aircraft management life cycle, accepting this may entail some risk.

At the same time, a second and potentially conflicting priority is to *transition ACPs into Air Force combat units as quickly as possible.* Given that China is fielding many new military capabilities faster than the United States, Air Force and DOD leaders are unified around the need to accept more risk in fielding new forces for deterrence and warfighting.[20] Air Force Chief of Staff General C.Q. Brown summed up the urgency associated with speeding combat-ready technology to warfighters: "You can't be innovative and risk averse at the same time...we've got to be able to take a little bit of risk, and some things are not going to work. But as long as we're failing forward, that's [what] we need to be, so we can accelerate change. So, we don't lose."[21]

Given these challenges, a central problem facing the Air Force is how to aggressively manage the operational, technological, and budgetary risks involved in quickly developing and fielding ACPs. This will require new thinking and innovative methods for producing ACPs at a speed and scale that exceeds most other military aircraft programs; new technologies—most critically, AI—to increase ACP survivability and improve their performance in contested air environments; and new operating concepts for teaming inhabited and uninhabited aircraft.[22] Toward this end, the Air Force is actively considering every aspect of UAV innovation, including a broad vision for the multiple missions a family of ACPs might perform as depicted in Figure 1.[23]

Figure 1. Air Force Research Laboratory Depiction of ACP Mission Portfolio. See Appendix A for additional details on ongoing efforts to support ACP development across the Air Force and DOD. Source: Air Force Research Laboratory

Accelerating ACP development will also require the Air Force to win the support of DOD's leadership, Congress, the defense industry, and other stakeholders as the Air Force prepares to request significant resources for ACPs in the Fiscal Year 2024 budget. This will require clear articulations of the value proposition ACPs represent; the challenges and opportunities relating to their fielding; and a flight plan for their rapid design, development, and employment.

To assist in these tasks, the Mitchell Institute for UAV and Autonomy Studies (MI-UAS) launched a series of projects to develop insights for a family of Air Force ACPs. MI-UAS derived the key findings and recommendations in this report from independent research and a three-day workshop that convened Air Force, DOD, and industry experts to examine the value proposition of ACPs. During the workshop, operators, engineers, and scientists provided their perspectives on the potential roles and missions of ACPs, the capabilities and numbers of ACPs needed to conduct long-range penetrating strike missions when teamed with inhabited aircraft, and their costs and benefits relative to strike packages without ACP capabilities.

Workshop Approach

Drawing on the Mitchell Institute's resources and position as the only think tank in the nation dedicated to the study of aerospace power, the Mitchell Institute convened more than 40 UAV and airpower subject matter experts to explore the role of ACPs in a near-term conflict with China.[24] These experts were asked to plan long-range strike missions to support a major operation to blunt and then defeat a near-term Chinese invasion of Taiwan.[25] The scenario assumed that China would commence its invasion with large missile salvos against Taiwan and U.S. air bases in the Western Pacific. It also assumed that Chinese fighters and surface-to-air missile (SAM) batteries and other defenses would aggressively target U.S. aircraft and create a highly contested battlespace environment throughout the conflict.[26]

Taking inspiration from the warfighter adage "start with the target and work backwards," the workshop group was split into three teams to plan long-range strike missions for three specific operational vignettes and then consider whether and how ACPs could increase the effectiveness of stealthy bombers and other mission forces. The three vignettes consisted of a maritime strike against a Chinese surface action group (SAG) sailing northeast of the Taiwan Strait; a hunt for ballistic missile teleporter erector launchers (TELs) deployed from two garrisons on mainland China; and an airbase attack on a Chinese H-6 bomber base on mainland China. These vignettes were designed to vary geography, threats, and target types to allow an assessment of similarities and differences between mission capability and capacity gaps and potential ACP solutions. While operators primarily focused on planning their missions and determining force structure and capability needs, scientists and engineers participating in the workshop provided a sounding board on the maturity of UAV technologies and estimated the design feasibility and cost of notional ACP types proposed by the teams.

MI-UAS Workshop Methodology

1. **Build a baseline force and assess gaps:** Participants selected from a near-term force inventory to design a baseline force package around stealth bombers conducting penetrating strike missions. We then asked participants to identify key capability gaps and assess operational risk.

2. **Design an ACP force to mitigate gaps:** Participants next designed a set of ACP types to mitigate mission gaps. They also roughly estimated the cost of their ACPs. A key aspect of this exercise was making trade-offs between capability, capacity, and cost.

3. **Rebalance ACP types on a budget:** Participants traded off ACP capability attributes in response to a cost challenge to create a revised package consisting of the base force plus ACPs. They then re-assessed operational risk.

Key Findings

A central insight developed during this project is that **large numbers of lower-cost, next-generation ACPs could help offset serious force structure shortfalls that now threaten the Air Force's ability to present a combat-credible force.** Workshop experts did not see ACPs as a substitute for inhabited stealth bombers and fighters, which would play a central role in blunting and halting invasion forces as part of a U.S. campaign to deny a Chinese fait accompli.[27] They concluded that ACPs could help mitigate serious gaps in the Air Force's ability to conduct long-range penetrating strikes, and potentially do so at a relatively low cost. If fielded quickly enough and in large enough numbers, these ACPs could complement the Air Force's most capable stealthy platforms and become a main contribution to DOD's effort to build a resilient force that shifts the cost exchange ratio in favor of the United States.

Experts also identified several major issues that would benefit from further analysis. There remains a significant degree of uncertainty across the Air Force's operational and science and technology communities on the maturity of certain key ACP technologies, especially AI. There are also divisions over whether legacy methods of assessing new aircraft development and production costs should apply to ACPs, given emerging manufacturing processes and technologies. And, while experts convened by the Mitchell Institute widely agreed it would be beneficial to diversify and simplify ACP production, they were unsure if DOD's current acquisition processes could support such an effort.

Despite these challenges, experts agreed the Air Force must accept these risks if it is to quickly develop and field a family of ACPs. In their estimation, the potential to increase the survivability of inhabited aircraft like stealthy bombers and force an adversary to confront a more complex threat outweighed the risks associated with fielding ACPs at scale as quickly as possible. While ongoing Air Force prototyping and experimentation programs are intended to do this, experts called for additional opportunities for operational experts and industry to collaboratively assess and experiment with ACP concepts. This project is a step toward informing the Air Force's ACP development efforts so that stakeholders inside the Pentagon, on Capitol Hill, in industry, and in the American public have the information they need to make informed decisions about what could be most significant change to the service's force design in decades.

Outline

The remainder of this report examines insights gained from the Mitchell Institute workshop on penetrating strike and implications for ACP development. It first describes workshop experts' assessments of key capability and capacity gaps for penetrating strike missions and the extent to which they saw those gaps increasing the risk of mission failure. It then provides an overview of expert views on how ACP concepts and technology might mitigate these gaps, reduce risks to penetrating strike missions, and provide advantages over the adversary. Next, it discusses a number of key challenges and opportunities that experts identified as critical for the Air Force to rapidly address as it pursues ACPs. Finally, it closes with recommendations for the Air Force.

Penetrating Strike Packages Currently Lack Key Capabilities and Capacity

Advanced bombers play a central role in the U.S. military's strategy to deny a peer adversary from achieving its campaign objectives in a major act of aggression. For instance, one of the most effective ways to deal with Chinese missile salvos against U.S. and allied forces and bases might be to penetrate highly contested airspace to attack the *sources* of those salvos while also attriting China's invasion forces.[28] These efforts would be part of a broader denial operation to blunt and then halt Chinese forces invading Taiwan or other areas on China's periphery as outlined by the 2022 NDS.[29] Penetrating strike assets like the B-2 Spirit and the B-21 Raider will be critical to such efforts because they uniquely possess the stealth and striking power required by theater commanders to destroy highly mobile naval forces, amphibious assault ships, missile launchers, and long-range air forces on which China relies to conduct power-projection operations.

Yet workshop experts assessed that the Air Force's current force of 141 total bombers—which includes only 20 stealthy B-2s capable of operating in contested areas—lacks sufficient survivability, lethality, and penetrating strike capacity for a major conflict with China. Mitchell Institute asked these experts to select forces from the current Air Force inventory to support stealth bombers conducting three penetrating strike missions. The experts then identified gaps in their baseline force packages that would pose unacceptable risk to their assigned missions For the purposes of the workshop, we defined risk to mission as the force's *capability and capacity* to conduct current operations at an acceptable human, material, and financial cost, as well as its expected performance against emerging or anticipated threats as laid out in the defense strategy.[30] The experts widely agreed that the current force structure does not adequately support the capability and capacity requirements of penetrating strike missions.

Experts Identified Significant Mission Gaps in ISR and Counterair

The Mitchell Institute did not examine the Air Force's overall readiness for a conflict with China, but workshop experts did identify a variety of capability and capacity gaps for discrete long-range penetrating strike missions. Across the workshop vignettes, participants cited serious gaps in intelligence, surveillance, and reconnaissance (ISR); command, control and communications (C3); and a variety of counter-air missions, the latter of which were critical for bringing forces to bear for attack, suppressing integrated air defenses, and escorting bombers into heavily contested air environments (see Table 1). Workshop experts subsequently focused their efforts on determining ACP designs that would help mitigate these shortfalls.

Insufficient ISR to track moving targets. The ability to track moving targets represented a critical capability and capacity gap for all three of the workshop's penetrating strike baseline forces. The workshop scenario assumed China would employ offensive kinetic capabilities, jamming, and cyberattacks early in their campaign in an attempt to blind U.S. surveillance assets and degrade or deny U.S. communications and precision navigation and timing.[31] DOD leaders have expressed concern over China's ability to attack current generation, non-stealth U.S. ISR capabilities and deny their access to the battlespace.[32] Even if

		Maritime Strike Base Force		TEL Hunt Base Force		Airbase Attack Base Force	
		Capability Gap	Capacity Shortfall	Capability Gap	Capacity Shortfall	Capability Gap	Capacity Shortfall
ISR to locate and track moving targets		Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall
Command, control, communications		Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall
Counterair	Attack	Not Critical for Workshop Vignette	Not Critical for Workshop Vignette	No Gap/Shortfall	Significant Gap/Shortfall	Not Critical for Workshop Vignette	Not Critical for Workshop Vignette
	SEAD	No Gap/Shortfall	Significant Gap/Shortfall	No Gap/Shortfall	Significant Gap/Shortfall	No Gap/Shortfall	Significant Gap/Shortfall
	Escort	Not Critical for Workshop Vignette	Not Critical for Workshop Vignette	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall	Significant Gap/Shortfall
	Defensive counterair	No Gap/Shortfall	Significant Gap/Shortfall	Not Critical for Workshop Vignette	Not Critical for Workshop Vignette	Not Critical for Workshop Vignette	Not Critical for Workshop Vignette
Electronic attack		No Gap/Shortfall	No Gap/Shortfall	Not Critical for Workshop Vignette	Not Critical for Workshop Vignette	No Gap/Shortfall	Significant Gap/Shortfall

No Gap/Shortfall — Significant Gap/Shortfall — Not Critical for Workshop Vignette

Source: Mitchell Institute

Table 1: Experts identified significant capability and capacity gaps across base force penetrating strike mission packages. See Appendix B for a more detailed summary of these gaps.

U.S. ISR satellites were available, experts were not confident that they would be able to maintain custody over moving targets due to a lack of continuous coverage of target areas from low earth orbit, uncertainty over the ability of satellites to track large numbers of moving targets, and competing theater priorities for space-based ISR. In fact, the workshop's operational experts were so pessimistic about the survivability of the Air Force's current-generation inhabited ISR assets that they determined mission success would require penetrating bombers themselves to employ active and passive sensors to find and track moving targets. This means the bombers would have to emit periodically, an action that would increase the potential for enemy sensors to detect and track them.

Insufficient counterair to suppress threats to penetrators. Experts also identified multiple counterair capability and capacity gaps for all workshop baseline force packages. These included gaps for suppression of enemy air defenses (SEAD), bomber escorts, defensive counterair, and offensive counterair attack operations.

Experts cited a specific concern about a lack of penetrating counterair capabilities, which they saw as essential for suppressing air-to-air and surface-to-air threats. They expressed concern that these gaps cannot be filled by current inhabited aircraft, which lack sufficient range to accompany penetrating bombers deep into highly contested areas—a finding that also reflects public statements from the Air Force.[33]

To put the problem in perspective, the Air Force's most advanced 5th generation fighters have access to just two U.S. air bases, both in Japan, from which they can reach the Taiwan Strait without aerial refueling. By contrast, China has 39 airbases within 500 miles of Taipei.[34] The introduction of the Air Force's Next Generation Air Dominance (NGAD) system might address some of these issues, but the Mitchell Institute workshop conflict scenario assumed it had not yet joined the operational inventory.

Experts Assessed that Gaps Pose a Significant Risk to Penetrating Strike Missions

Overall, workshop experts assessed an increased risk to penetrating bomber missions due to capability gaps in penetrating ISR, counterair, and other areas (these gaps are described in detail in Appendix B). In their estimation, these gaps would likely limit the ability to mass a decisive force; reduce capacity to sustain large-scale strike operations; and degrade command, control, and communications.[35]

Obstacles to massing decisive force. Workshop experts noted the United States and allied militaries lack sufficient forces permanently or rotationally postured in the Indo-Pacific to immediately respond to blunt Chinese aggression. Mobilization of ground and naval military assets garrisoned in the U.S. homeland could be delayed or even halted if China attacks the U.S. Transportation Command's logistics networks with kinetic attacks, cyberattacks, and/or electromagnetic warfare measures.[36] Fixed airfields and carrier strike groups operating in the Western Pacific are also attractive targets for China's sensor networks and long-range missile attacks at the start of hostilities. This risk led the workshop experts to focus heavily on developing alternatives to basing ACPs at large, fixed airfields so they could generate ACP sorties despite Chinese attacks.

Insufficient capacity to sustain large-scale strike operations. Attrition of Air Force aircraft and aircrews would be an acute problem for sustaining large-scale strike operations against China, particularly in a protracted conflict. General C.Q. Brown has warned that in a great power conflict, U.S. and allied aircrews could face high combat attrition rates more akin to World War II than in recent conflicts.[37] There is also a growing body of evidence that China's air and missile strikes on U.S. and allied airbases could significantly degrade the Air Force's sortie generation operations.[38] Workshop experts were concerned that high attrition rates, combined with a greatly diminished force structure, could severely degrade the Air Force ability to replenish its combat losses. Exacerbating factors include the U.S. industrial base's lack of capacity to surge platform and munitions production, as well as the months and even years required to train experienced aircrews and agile combat support personnel.[39] Given these concerns, workshop experts emphasized the development of large numbers of low-cost ACPs to increase theater commander loss tolerance.

Degraded command, control, and communications. Experts were concerned that Chinese counterspace weapons and offensive electromagnetic warfare could deny multiple types of U.S. space-based communications; radar systems; and positioning, navigation, and timing support needed for precision strikes in contested environments.[40] Loss of this support would make it difficult to connect sensors and shooters at scale across the theater—despite DOD's ambitious Joint All Domain Command and Control (JADC2) effort to do so.[41] This concern drove experts to focus heavily on opportunities to develop resilient datalinks and rely more heavily on autonomy, which would allow ACPs to operate independently of human control.

Overall, Experts Assessed Risk to Mission as Significant to High

Given these capability and capacity gaps and the risks they introduce, workshop experts were concerned about the ability of their baseline force packages to successfully execute their missions. The two workshop teams tasked with planning for attacks that would penetrate mainland China—the missile TEL hunt team and the airbase

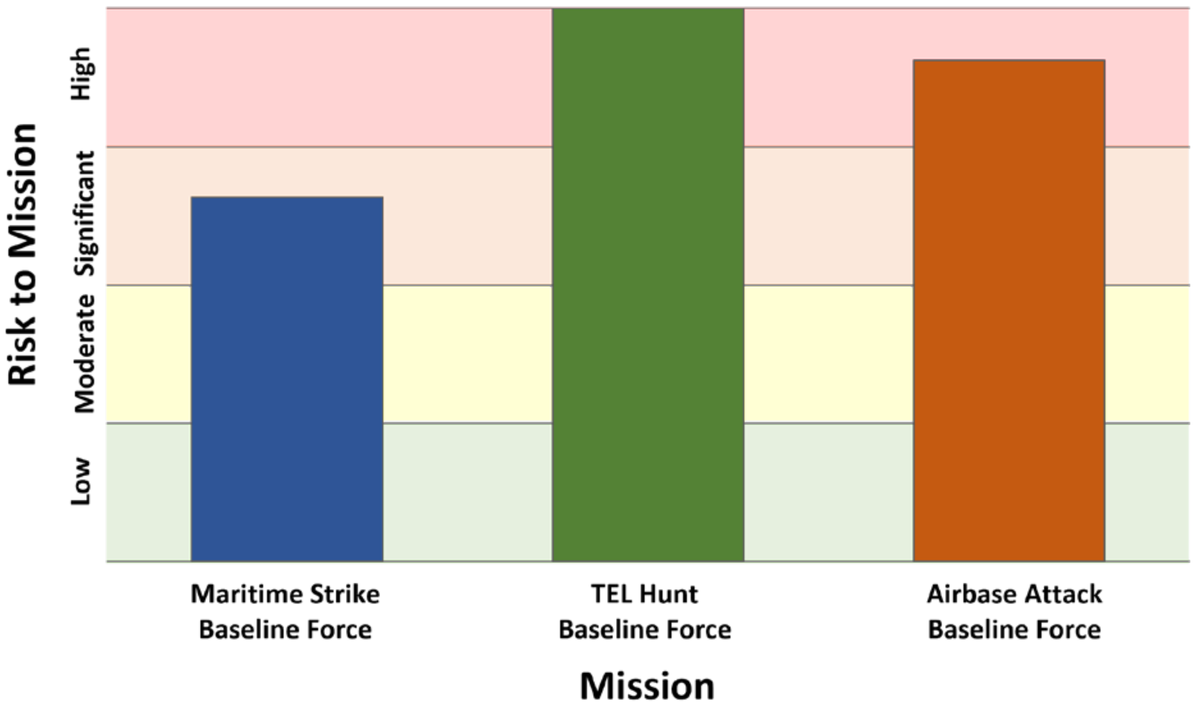


Figure 2: Risk to mission ranged from significant to high for all three penetrating strike vignette baseline force packages. Risk to the TEL hunt and airbase attack missions were considered so excessive that a theater commander may not direct their execution.

attack team—argued the potential for mission failure would be so high due to attacks on scarce and costly stealth bombers that an air component commander may not approve mission execution (see Figure 2). The maritime strike team assessed their risk to mission as somewhat lower but still significant. Experts planning for this vignette were also concerned about insufficient ISR capability and capacity, given the vast expanses of the Indo-Pacific and Chinese A2/AD capabilities in China's coastal maritime environment.

Taken together, the workshop experts identified a range of capability and capacity gaps facing penetrating strike packages and assessed risk to these missions as significant to high. These findings reflect the views of senior Air Force leaders, including Secretary Kendall, who summed it up: "We're the dominant power until you get within about 1,000 miles of China, and that starts to change."[42] A failure to manage risks to mission in a conflict with China could have disastrous results for the Air Force and the United States as a whole. UAVs could provide a means to mitigate some of this risk because of their most basic feature: they remove aircrews from the battlespace. Reducing risk to aircrew was, of course, a priority during the counterinsurgency conflicts of the last two decades, but it was not a decisive factor in battlefield performance; aircrew casualties occurred in small numbers relative to past wars and did not significantly impact the ability of forces to generate combat power.[43] Yet in a great power war, rapid and significant losses of aircrews and aircraft would directly impact mission outcomes and could increase the odds of defeat. In this context, reducing risk to force becomes more than an ethical obligation: it is a prerequisite for deterrence and prevailing in conflict.

ACPs Offset Shortfalls and Mitigate Risks for Penetrating Strikes

After identifying key capability and capacity gaps for their penetrating strike missions, we next asked workshop experts to consider how new concepts and technologies might be applied to next-generation UAVs to support penetrating strike packages. For each operational vignette, experts could design up to three ACP types, as depicted in Table 2.

	Maritime Strike			TEL Hunt			Airbase Attack		
	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3
ACP Role	Counterair	ISR	Strike	Counterair	Counterair, ISR	Counterair, ISR	Counterair	Counterair	Electronic Warfare
ACP Missions	Defensive Counterair	ISR, Communications Relay	Strike	Escort, SEAD	ISR, SEAD, Offensive Counterair attack (MALD-class weapons)	ISR, SEAD, Offensive Counterair attack (swarm attack concept)	Escort	SEAD	Jamming
Quantity of ACPs for Mission Packages	40	10	20	10	144 (24 per bomber)	120 (20 per bomber)	8	16 initially, increased to 32	8

Source: Mitchell Institute

Table 2: Experts designed three notional ACP types for each penetrating strike mission. These designs were focused on addressing gaps in penetrating ISR and counterair capabilities and increasing combat mass.

Most notably, experts preferred force package designs that would distribute mission capabilities across large numbers of ACP platforms rather than concentrate them on a small number of exquisite aircraft. This design would increase mission package resiliency to losses, present an adversary with a more complex air defense challenge, and help reduce individual ACP unit costs.

Workshop experts also prioritized counterair missions; six out of the nine ACP types were assigned to that role. For the missile TEL hunt team and the airbase attack team, experts saw it as particularly important to design ACP variants to mitigate long-range fighter escort capability gaps. They saw this mission as essential for protecting stealthy bombers conducting long-range strikes into mainland China (see ACP 1 for each team in Table 2). Experts also were concerned about capability and capacity gaps for ISR and SEAD. The missile TEL hunt team was particularly concerned about exposure of their inhabited bombers to air defenses while they searched for targets, so it designed all three of their ACPs types to conduct SEAD.

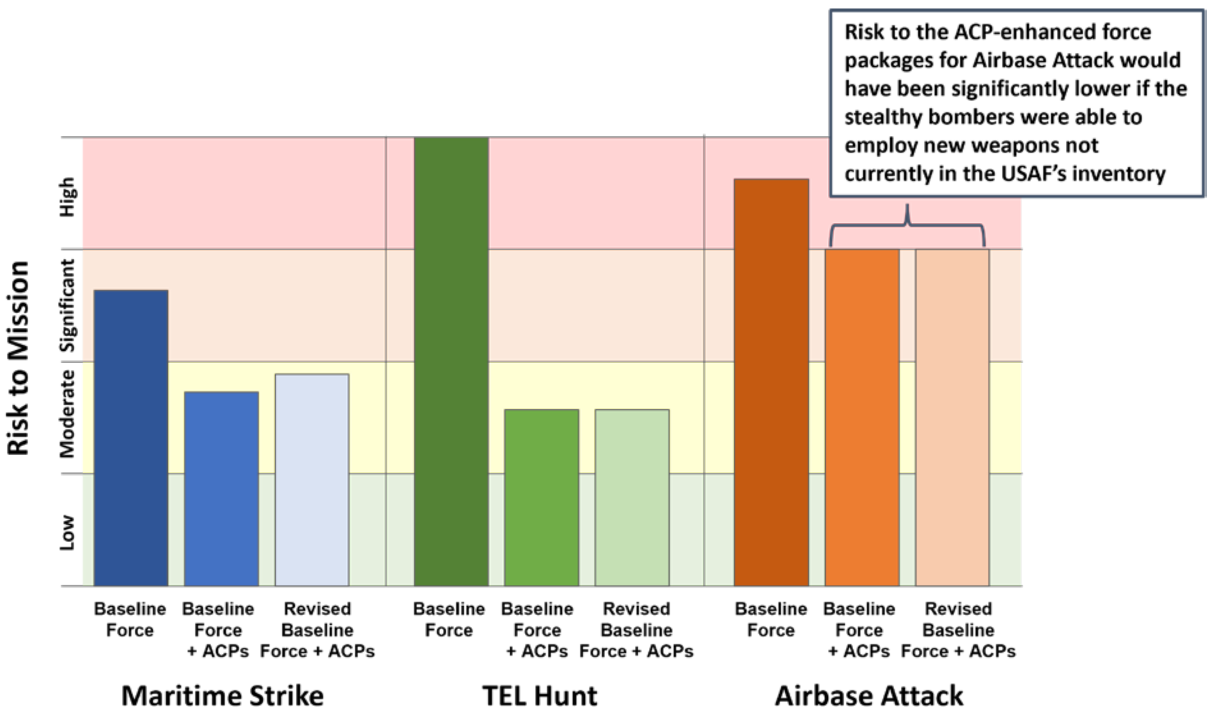
ACPs Decreased Risk to Mission

Workshop experts developed operating concepts for using their ACPs with penetrating bombers to reduce risk and achieve mission success. They assessed that these new ACP capabilities and concepts would improve operational effectiveness and reduce risk over their baseline force packages as shown in Figure 3.

Employing the Wrong Munitions Drives up Risk to Mission

While munitions were not the primary focus of this project, the impact of having the wrong munitions mix was striking, particularly for the workshop airbase attack team. That team determined risk to mission would have been significantly lower for their ACP-enhanced force packages if their stealthy bombers could employ a new class of precision-guided munitions (PGMs) that were optimized to be carried internally. The Air Force's current PGM inventory largely consists of very short-range, direct attack munitions of the kind used for strikes in permissive environments over the last two decades, and a much smaller quantity of long-range stand-off cruise missiles like JASSMs. Use of direct attack weapons would require bombers to fly close to their targets, which would increase the risk that enemy defenses that typically surround high-value installations like PLA airbases would find, track, and attack them. On the other hand, using long-range air-launched cruise missiles against airbases would reduce the number of aimpoints the strike package could attack because its bombers could carry fewer of these larger weapons. Moreover, most long-range stand-off attack weapons cannot carry warheads that are large enough to destroy hardened facilities located on Chinese airbases, such as weapon storage facilities, C3 centers, and some aircraft shelters. A major recommendation of this project is that the Air Force should develop a new class of mid-range PGMs that would increase the lethality and survivability of stealth bombers conducting penetrating attacks into contested environments.

For more on munitions issues, see Mark A. Gunzinger, *Affordable Mass: The Need for a Cost-Effective PGM Mix for Great Power Conflict* (Arlington, VA: The Mitchell Institute for Aerospace Studies, November 2021).



Source: Mitchell Institute

Figure 3: Risk to missions declined after ACPs were introduced. Risks remained at lower levels even after some ACP capabilities were reduced to decrease their unit cost in the revised baseline forces.

The second bar for each team in Figure 3 (representing the baseline force plus the new ACP types) shows this significant drop in risk to mission. Risk declined from significant to moderate for maritime strike, from high to moderate for the missile TEL hunt, and from high to significant for airbase attack. The third bar for each team (representing the revised baseline force plus the new ACP types) shows that risk remained low even after we asked the experts to trade off some of their ACP capabilities so we could assess their design sensitivity to costs. This finding suggests that some reductions in ACP capabilities may be possible without significantly decreasing their mission effectiveness.

ACPs Imposed Significant Costs

Experts' preference for bringing lower-cost ACP mass to the battlespace and using counterair ACPs to protect inhabited bombers reflected their concern with getting on the right side of the cost-exchange ratio. This has become more important as China built up its relatively low-cost offensive and defensive missile arsenal. As explained in 2017 by Lt Gen Steven Kwast, then commander of Air University, "When there's a $10 problem…you solve that problem for 10 cents, and you force your competition to solve it for a thousand bucks."[44]

However, experts also recognized the value of ACPs beyond out-of-pocket unit costs and identified a variety of other benefits that are important to mission success but harder to quantify. These include increasing bomber survivability while reducing an adversary's ability to counter precision strikes, expanding options for U.S. commanders while reducing the adversary's ability to participate and respond to multiple attacks, and creating war-winning advantages while attritting adversary forces and imposing other costs. While these benefits may not be easily captured in a cost-exchange ratio, the Air Force should consider them as it pursues its future ACP force design.

Increasing Bomber Survivability While Reducing an Adversary's Ability to Counter Precision Strikes

Experts employed mass to impose complexity on the adversary. Experts participating in Mitchell's Institute's workshop prioritized increasing the capacity of their force packages to attrit Chinese air defenses and to improve the potential for inhabited penetrating bombers to complete their missions. These objectives drove workshop teams to focus on designing ACPs for counterair operations. These ACPs could help neutralize threats by forcing an adversary to activate their air defense sensors and then deplete their surface-to-air missiles (SAM) and other kinetic defenses against ACPs rather than inhabited bombers. This would create opportunities for stealth bombers to attack their targets at much lower risk. RAND's David Ochmanek described the dilemma this ACP operating concept could create for SAM operators:

> Your scopes are flooded with things that you have to kill. If you don't kill those sensors, we are going to find you, and if we find you, we will kill you. So, we're creating a defilade, or camouflage, if you will, for the inhabited aircraft to hide behind.[45]

The airbase attack team employed this exact approach to complicate and delay the adversary's defensive targeting cycle. The team designed its ACP 2 with a synthetic aperture radar (SAR) to track mobile SAM launchers and equipped it with small, short-range precision-guided munitions to suppress them. When the Mitchell Institute imposed a budget constraint on ACP designs toward the end of the workshop, the team removed the SAR from half of their 16 ACP 2 types, which reduced costs enough for the team to double the number of ACP 2s they could acquire for their force package to 32. Although they lost a key ground moving target indicator (GMTI) sensor, the team assessed the risk to mission would remain much lower than their baseline risk. The larger force package would require the adversary to counter a more complex, diverse threat without knowing what it should target first. The resiliency of their ACP-enhanced force was increased by the fact that each ACP would have a radar signature matching the B-21's low observability. This would further complicate an enemy's ability to detect an attack, determine targeting priorities, and then launch efficient counterattacks without temporarily exhausting their kinetic defenses.

Similarly, the team planning for the missile TEL hunt mission used its ACP 2s in ways that would increase bomber survivability and complicate the adversary's decision-making. Their ACP 2 platform was primarily designed as a small, lower-cost expendable loitering munition that could be launched in packages of 24 from B-21s to find missile TELs and then relay target updates to the B-21s. Using ACP 2 platforms in this way meant that inhabited bombers would not need to emit to locate and track mobile targets. The ACP 2 platforms also could increase the survivability of inhabited bombers by selecting and then engaging previously undetected pop-up SAM threats. The missile TEL hunt team complemented their ACP 2 platforms with ACP 3 platforms, another longer-range loitering munition that could be rocket-launched by B-52 bombers from stand-off ranges. The combined use of ACP 2s and ACP 3s allowed the missile TEL hunt team to increase its counter-SAM mass in the battlespace to create a complex challenge for adversary defenses.

Expanding Options for U.S. Commanders While Reducing the Adversary's Ability to Anticipate and Respond to Multiple Attacks

Experts employed ACPs to free some stealthy bombers for other missions. As they conducted their mission planning, experts determined that ACPs could expand options for penetrating strike at the theater level. They took advantage of ACPs to reduce the number of stealthy bombers they needed for their missions. This freed some high-value bombers and crews, which could then be used to simultaneously conduct penetrating strikes elsewhere in the theater. For example, the airbase attack team increased the effectiveness of their mission force package by shifting responsibility for SEAD from bombers to their ACP 2 platform. They designed their ACP 2 type as a fixed-wing UAV with a small SAR, an electronic countermeasures (ECM) pod to jam adversary signals, and a small number of anti-radiation guided missiles. They also added ECM to their ACP 1s, another fixed-wing aircraft. The team estimated the introduction of these ACPs would allow the theater commander to re-task some bombers to perform other critical missions that would otherwise not be performed due to shortfalls in penetrating long-range strike forces. This would also create a more complex challenge for PLA defenses by forcing them to simultaneously deal with multiple distributed penetrating strikes.

Experts also identified ACPs as a means to diversify and increase the resiliency of the Air Force's theater posture. Using ACPs at scale can also create opportunities to diversify the Air Force's posture in a theater of operations. A more dispersed and varied posture in the Indo-Pacific would require the PLA to fly more ISR sorties and expend more weapons to find and attack Air Force combat forces across the theater, and then determine attack results. This would have the effect of increasing the cost of the PLA's attacks and raising the uncertainty regarding their effectiveness. Experts also assessed it would be advantageous to deploy ACPs closer to the battlespace rather than co-locating them with Air Force bombers along the Pacific's Second Island Chain, northern Australia, and other distant bases. Locating ACPs closer in would reduce their range requirements, which in turn would reduce their required fuel capacity, size, and cost.

These posture initiatives are reflected in Table 3, which depicts range and take-off and landing preferences for the workshop's nine proposed ACP designs. Workshop teams were particularly interested in operating from roads or from shorter civilian landing strips that are plentiful in the Pacific region because they understood the need to reduce reliance on existing main operating base runways that will be attacked by China's missile forces.[46] To reduce the logistics burden of operating from locations inside China's missile envelope, the TEL hunt mission team designed expendable ACP types (ACP 2 and ACP 3) that entirely eliminated the need to recover them at airbases after missions.

	Maritime Strike			TEL Hunt			Airbase Attack		
	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3
ACP Role	Counterair	ISR	Strike	Counterair	Counterair, ISR	Counterair, ISR	Counterair	Counterair	Electronic Warfare
ACP Missions	Defensive Counterair	ISR, Communications Relay	Strike	Escort, SEAD	ISR, SEAD, Offensive Counterair attack (MALD-class weapons)	ISR, SEAD, Offensive Counterair attack (swarm attack concept)	Escort	SEAD	Jamming
Quantity of ACPs for Mission Packages	40	10	20	10	144 (24 per bomber)	120 (20 per bomber)	8	16 initially, increased to 32	8
Range	2,000 nm	1,000 nm	1,000 nm	3,000 nm	600 nm	Small UAS: 1 hour search across 20 nm radius Rocket: 1,000 nm	3,000 nm	3,000 nm	3,000 nm
Take-off and Landing	Runway < 5,000 ft	Road, runway < 5,000 ft	Runway < 5,000 ft	Road, runway < 5,000 ft	Air launched from stealth bomber	Air launched by rocket from stand-off B-52	Runway < 5,000 ft	Runway < 5,000 ft	Runway < 5,000 ft

Source: Mitchell Institute

Table 3: In contested environments, experts preferred to operate ACPs from short non-military runways and roads, or air launch them if possible. Operating ACPs independent of major airbases was intended to reduce the risk of enemy large-scale air and missile attacks that would suppress ACP sortie generation operations.

Creating War-Winning Advantages while Attritting Adversary Forces and Imposing Other Costs

Workshop experts also considered using ACPs in ways that would more broadly impose costs on Chinese forces in a major conventional conflict by increasing the Air Force's attrition resiliency, more widely distributing risk, and reducing the vulnerability of C3.

ACPs can increase attrition resiliency. Workshop experts and senior Air Force leaders consulted after the workshop indicated that ACP cost imposition potential could go well beyond destroying enemy force equipment at relatively low out-of-pocket cost. The most important benefits of ACPs may, in fact, be their ability to reduce friendly aircrew attrition. On one level, this is obvious because all UAVs reduce that risk by removing aircrew from the battlespace. On another level, reducing aircrew risk would take on even greater importance in great power conflict. Introducing large numbers of low-cost ACPs to the battlespace could minimize the need to replace aircrew, aircraft, and their agile combat support personnel. In a conflict against a peer adversary that has technological parity with the United States, such an advantage in human resources could prove decisive.[47] Reducing aircrew losses also would have second and third order benefits beyond the immediate gain in attrition resiliency. It could help pare the direct costs and time required to train new pilot replacements, as well as the indirect costs of combat search and rescue aircraft and crews seeking to recover pilots downed in combat.[48] In short, minimizing aircrew attrition by using ACPs at scale could present a significant U.S. advantage, particularly in a protracted conflict with China.

ACPs can distribute risk. During the workshop, experts preferred to spread modest capabilities across a larger number of platforms in their force packages and operate ACPs from dispersed expeditionary locations. From a cost imposition perspective, distributing risk in these ways would have two benefits.

First, spreading capabilities across multiple ACPs would increase force resiliency and cause the adversary to expend rounds on lower-cost, less capable systems that could be more easily replaced than inhabited aircraft. Workshop experts also designed ACPs with signatures in the electromagnetic spectrum that were similar to inhabited penetrating aircraft. Their logic was that the adversary would not be able to identify which aircraft had the greatest ability to damage or destroy targets, and therefore had to attack every potential threat.

Second, experts sought to distribute their ACP posture across the theater. The goal was to force the adversary to fly more ISR sorties and expend more weapons to find and attack Air Force operating locations, increasing the cost of its attacks and creating uncertainty about their effectiveness.[49]

ACPs can reduce command, control, and communications (C3) vulnerabilities. Technologies that introduce greater levels of autonomy into ACPs could also impose costs, particularly against China, which has invested heavily in counterspace weapons systems and electronic warfare capabilities to degrade or deny U.S. and ally C3 networks.[50] Decentralizing C3 to a larger number of systems operating with some degree of independence would help offset kinetic and non-kinetic countermeasures that China has spent decades developing to target U.S. communication networks.[51] Experts noted that the introduction of autonomous systems, supported by AI, could also speed up U.S. decision-making in the battlespace, reduce reliance on fragile datalinks, and eliminate or reduce the need to receive commands from bomber crews, thereby reducing the need for bombers to emit signals. Of course, autonomy can also introduce more complexity into decision-making, and so it will be important to proactively manage human-machine interactions to ensure autonomous ACPs meet warfighter needs and effectively operate within broader U.S. policy constraints.[52]

Overall, workshop experts saw ACPs as an effective means to mitigate key capability gaps, significantly reduce risk to mission, and shift cost exchanges in favor of the United States. Large numbers of lower-cost ACPs were seen as a key means to increase the survivability, lethality, and capacity of the bomber force, while at the same time raising the costs of aggression for China. ACPs could provide an advantage to the United States in tactical engagements; diversify options at the theater level; and provide the sheer mass required to overwhelm, outlast, and ultimately prevail over a peer adversary with its own high-tech forces.

ACPs Present New Challenges and Opportunities

Operators, scientists, and engineers participating in the Mitchell Institute's ACP workshop recognized that harnessing the potential of ACPs will require the Air Force to tackle serious challenges associated with fielding new weapon systems on the frontier of technological advancement. These include uncertainty over how to assess the cost of ACPs; the maturity of critical technologies, such as AI; and the viability of processes to rapidly manufacture ACPs in peacetime and surge production in crises. Experts widely agreed that the challenges are likely surmountable, but, given the severity of the threats facing U.S. forces, the Air Force will need to take prudent risks to rapidly field ACPs rather than waiting for 100 percent capability solutions. Clearly defining these challenges is an important step toward aggressively managing that risk.

Challenge: DOD, Air Force, and Industry Do Not Yet Share a Common Approach for Assessing ACP Costs

Workshop experts were divided over the most appropriate approach to assessing ACP aircraft costs. This is a vital concern, because the Air Force sees the value of ACPs as tightly linked to their potential to increase combat mass while keeping program costs manageable, given competing priorities and limited resources. The Air Force's preferred ACP development approach is to design them with modest capabilities so that they cost less per unit, and therefore can be purchased in larger numbers.[53] Yet, in the workshop and subsequent discussions with Air Force cost assessment officials, it became clear there is no broad consensus on how low ACP costs should be. Should ACPs cost less than the inhabited aircraft they are supporting? Should they cost less than the threats they are designed to engage? Or do they just need to cost less than alternative technologies that could provide the same capabilities?

Even more fundamentally, Air Force and industry experts raised important questions about assumptions and methods that should be used to estimate the costs of ACPs. In the aerospace industry, it is common to use parametric estimating models, which use a statistical relationship between historical aircraft cost data and other variables unique to an aircraft design, such as specific costs for a new sensor, to estimate a new aircraft's cost.[54] These models yield aircraft cost estimates that are typically priced on a dollar-per-pound basis, which means that aircraft size and empty weight are the main, but not only determinants of cost.

Yet many within the Air Force aircraft design industry are starting to question whether models that use historical aircraft data are still relevant to ACPs. In their view, new thinking on aircraft life cycle management—from production to acquisition, operations, and sustainment—is required to inform ACP cost debates. These changes, in turn, drive a fundamentally different set of assumptions about aircraft costs.

The Air Force Research Laboratory (AFRL) has led the charge in challenging current cost assumptions and their utility for estimating ACP costs. Their goal is to build ACPs that cost around $600 per pound at empty weight, compared to $4,000 to $8,000 per pound for aircraft in the Air Force's existing ISR, strike, and command and control inventory.[55] One of the main reasons for this optimism is their belief that much smaller aircraft can carry far more sensor and payload weight than previously assumed, and new approaches for manufacturing, operations, and sustainment can reduce their total life cycle costs (see "A New Way to Think About ACP Costs"). Yet some Air Force and industry cost assessors are more cautious on the potential for these factors to reduce ACP cost.[56] One common point of agreement seems to be the need to collect more data to determine if more optimistic ACP costing assumptions will prove out.[57]

A New Way to Think About ACP Costs

During the Mitchell Institute workshop and in subsequent discussions with Mitchell Institute, Air Force officials have indicated the following framing considerations give them a reason to question the validity of using legacy aircraft costing models and assumptions to estimate ACP costs.

Increased production efficiency. Reducing ACP production times could reduce program cost. Composites and new manufacturing processes could reduce touch labor and number of required aircraft parts. Rather than laying up composites by hand with expensive tools over many days, AFRL is exploring automated processes and large composites to build aircraft structures in a single shift.

Reduced complexity. The disaggregation of mission capabilities across different ACP variants and the introduction of simpler, smaller, and cheaper ACP sensors could make their airframes easier to manufacture and maintain. This could help reduce their flyaway cost, manufacturing time, and maintenance requirements. Modularity—which would allow for easy software changes—might also reduce the need for complex software integration, a cost driver in many modern aircraft.*

Expedited/reduced flight testing. Testing consumes considerable time and resources in military and civilian aircraft development programs. Digital engineering could allow the Air Force to iteratively prototype, experiment, and test solutions in a virtual environment. This could reduce the need to make costly design fixes during the flight test stage of ACP development.

Lower flight safety standards. With no pilot onboard, it may be possible to reduce the time and manpower needed to turn ACPs between sorties. For example, Lt Gen Hinote has described how an ACP may not need to have its oil checked for particles every time it takes off.**

Reduced air worthiness standards. Uninhabited aircraft designed for shorter service lives do not need to meet the same airworthiness criteria as inhabited aircraft. According to AFRL, the structural integrity of inhabited aircraft are typically 1.5 times stronger than it needs to be. Reducing airworthiness standards for ACPs could reduce their structural weight and flyaway costs.

* See Aerospace Vehicle Systems Institute, "Exponential Growth of System Complexity," 2022.

** Valerie Insinna, "U.S. Air Force to start new experiments with Boeing's MQ-28 Ghost Bat drone," *Breaking Defense*, October 5, 2022.

During Mitchell Institute's ACP workshop, experts struggled with the lack of clarity on cost assumptions and methodologies. While they were optimistic that ACPs could cost much less than legacy inhabited aircraft programs both on a cost-per-pound basis and a total lifecycle cost basis, they lacked data to test that hypothesis. At the same time, they balked at determining costs using historical data because it risked inflating ACP estimates.

All of these cost issues came to the fore when Mitchell Institute convened a group of eight engineers with expertise in aircraft cost assessment to provide a rough estimate of flyaway costs for all nine workshop ACP types (see Table 4).[58] This team priced ACPs using an optimistic, but consensus-driven, assumption that ACPs would cost about $1,000 per pound and would be produced in significant numbers. The team also used multipliers to account for the additional costs of ACP sensors and other mission payloads, low observability, and mission computing requirements based on their own knowledge of how those systems are generally priced.[59]

Challenge: Some ACPs Will Need Capabilities That Increase Their Cost

Workshop operations and technology experts sought to balance their preference for using large numbers of lower-cost ACPs with giving ACPs capabilities to execute missions in a highly lethal threat environment. Their preference for sophisticated capabilities such as stealth and search and track radars for some ACPs suggest that it will be important not to overreach on reducing ACP unit costs, especially when assumptions underlying those costs remain untested.

	Maritime Strike			TEL Hunt			Airbase Attack		
	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3
ACP Role	Counterair	ISR	Strike	Counterair	Counterair, ISR	Counterair, ISR	Counterair	Counterair	Electronic Attack
ACP Missions	DCA	ISR, Comms	Strike	Bomber Escort, SEAD	ISR, SEAD, Offensive Counterair Attack	ISR, SEAD, Offensive Counterair Attack	Escort	SEAD	Jammer
ACP Empty Weight (lb.)	35,000	1,500	16,200	35,000	1,000	Small UAV: 50 lb. each	10,000	15,000	3,000
Fuel Load (lb.)	30,769	1,500	12,088	9,231	1,269	Battery powered)	3,500	7,000	3,500
Total Payload Weight (lb.)	7,000	400	5,400	7,000	500	• Rocket-launched clam shell: 1,200 lbs. • Each clamshell dispenses 20 UAVs • Each UAV: 50 lb. plus 5 lb. warhead	3,000	5,000	500
Gross Weight (lb.)	72,769	3,400	33,688	51,231	2,769	UAVs: 50 lb. each	16,500	27,000	7,000
ROM Flyaway Cost in $ Millions	60.7	4.2	16.4	60.7	1.7	11.0	28.2	29	8.9
Quantity in Team Force Packages	40	10	20	10	144 (24 per bomber)	120 (20 UAV per rocket clamshell)	16	8	8

Source: Mitchell Institute

Table 4: Eight workshop experts estimated the flyaway cost of ACPs on the basis of $1000 per pound, plus additional costs for sensors and payloads and low observability based on industry data. ACP costs ranged from a low of $1.7 million for a simple loitering munition up to $60.7 million for large, more capable counterair platforms.

	Maritime Strike			TEL Hunt			Airbase Attack		
	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3
Mission	Defensive Counterair	ISR, Comm Relay	Strike	Escort, SEAD	ISR, SEAD, Offensive Counterair attack (MALD class weapons)	ISR, SEAD, Offensive Counterair attack (swarm concept)	Escort	SEAD	Jamming
Survivability Not low observable (LO) LO, or VLO	VLO (fighter decoy)	LO	Not LO	VLO	VLO	Not LO, small size and flying low altitudes reduce some risk	VLO	VLO	VLO
Sensor (and cost)	AESA (high)	SAR (moderate)		AESA (high)	Low-cost SAR	Low-cost long wave infrared	AESA (high)	SAR (high)	
Air-ground	2 x Stand In Attack Weapon (SiAW)		2 x Long Range Anti-Ship Missile (LRASM)					6 x SiAW	
Air-to-air	4 x Advanced Medium Range Air to Air Missile (AMRAAM)			Joint Advanced Tactical Missile			6x AMRAAM		
Take-off and Landing	Runway < 5,000 ft	Road, runway < 5,000 ft	Runway < 5,000 ft	Road, runway < 5,000 ft	Air launch from stealth bomber	Air launch by rocket from B-52	Runway < 5,000 ft	Runway < 5,000 ft	Runway < 5,000 ft

Source: Mitchell Institute

Table 5: Experts in many cases preferred sophisticated capabilities that could increase costs.

As depicted in Table 5, workshop teams largely preferred ACP designs with low observable (LO) or very low observable (VLO) attributes to minimize their detection by enemy sensors, especially for strike scenarios like airbase attacks where surprise will be important to mission success. They also preferred sensors, especially for ACPs performing counterair missions, that are potentially costly. The air-to-air ACPs for all three missions were designed with active electronically scanned array (AESA) radar, which is used to search and track targets in the air. These radars can cost upwards of $3.2 million to integrate on an aircraft.[60] Similarly, experts preferred ACPs equipped with relatively high-cost missiles like the $2 million air-to-air Advanced Medium Range Air-to-Air Missile (AMRAAM) and the $4 million Long-Range Anti-Ship Missile (LRASM).[61]

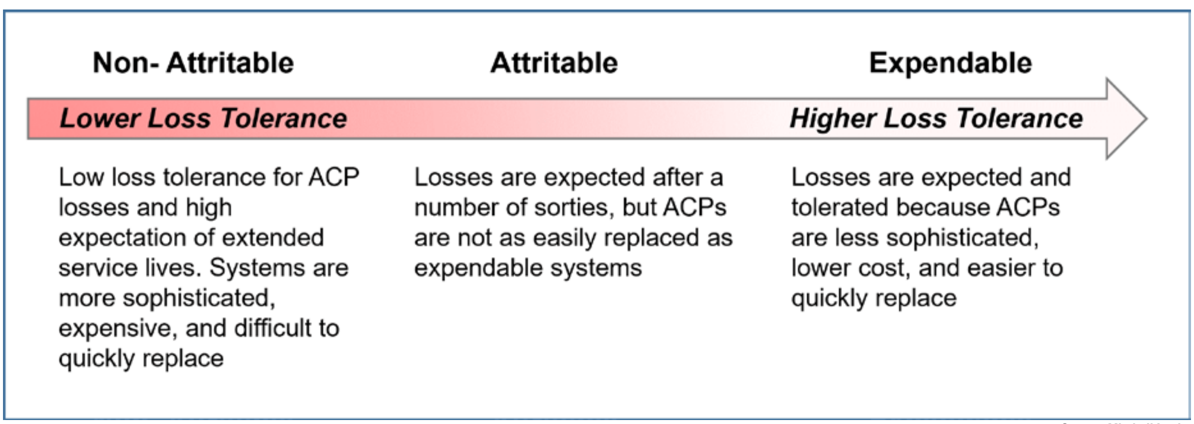
Despite their preference for some sophisticated capabilities, the experts were, for the most part, optimistic about the potential for these ACPs to become more affordable, smaller, and less complex while remaining combat effective. For example, both the maritime strike team and the missile TEL hunt team specifically indicated that low to moderately priced SAR options are starting to appear on the international market.[62] Experts were also optimistic about the potential to incorporate some degree of low observability in ACPs at an affordable cost. ACP basing was another consideration for reducing potential ACP costs. Workshop mission planning teams universally preferred to base their ACPs relatively close to the conflict, reducing their range requirements and size. They did, however, worry that this choice might increase ACP logistics and maintenance costs, calling attention to another area in further need of analysis.

Challenge: ACP loss tolerance is driven by cost and the unique characteristics of the conflict

During the workshop, experts assessed their tolerance for ACP losses on a spectrum. For the purposes of this project, “non-attritable” ACPs are difficult to replace and expensive at one extreme, and “expendable” ACPs—which some believe could include loitering munitions—are comparatively inexpensive and easier to replace.

Experts acknowledged integrating more sophisticated capabilities into ACPs could drive up their unit costs in the short term. Warfighters might be less likely to tolerate losses of relatively costly weapon systems in combat. However, they noted that other factors besides cost would affect their loss tolerance as well. Experts indicated that mission commanders would be highly tolerant of ACP losses—regardless of their out-of-pocket unit cost—if the ACPs were increasing mission effectiveness in a conflict with high combat attrition rates. More specifically, they indicated that the employment of ACPs to enhance the survivability of inhabited penetrating bombers, or to force an adversary to expend significant resources against ACPs, might be well worth their sacrifice. ACP loss tolerance may also vary over the course of a conflict. Replacing a very large number of less capable, lower-cost ACPs might be a cost-effective strategy in a short war, but it might become very expensive in a long one.

During the workshop, Mitchell Institute asked experts to consider their loss tolerance in the early days of war between the United States and China. Acting in their role as mission commanders, experts were generally tolerant of ACP losses because they saw them as tools to increase combat effectiveness; winning the war was the priority. Yet when they stepped back to consider ACP capacity requirements, they became more concerned about high ACP combat attrition. Given current budget limitations, they worried they may not be able to replace those combat losses with new ACPs if their out-of-pocket costs were too high.



Source: Mitchell Institute

Figure 4: Experts were more risk tolerant for ACPs they believed would be lower cost and easier to replace after a combat loss.

	Maritime Strike			TEL Hunt			Airbase Attack		
	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3	ACP 1	ACP 2	ACP 3
ACP Role	Counterair	ISR	Strike	Counterair	Counterair, ISR	Counterair, ISR	Counterair	Counterair	Electronic Attack
ACP Missions	DCA	ISR, Comms	Strike	Bomber Escort, SEAD	ISR, SEAD, Offensive Counterair Attack	ISR, SEAD, Offensive Counterair Attack	Escort	SEAD	Jammer
ROM Flyaway Cost in $ Millions	60.7	4.2	16.4	60.7	1.7	11.0	28.2	29	8.9
Risk Tolerance: expendable, attritable, or non-attritable	Non-attritable	Attritable	Attritable	Non-attritable	Expendable	Expendable	Attritable	Attritable	Attritable
Quantity in Team Force Packages	40	10	20	10	144 (24 per bomber)	120 (20 UAV per rocket clamshell)	16	8	8

Source: Mitchell Institute

Table 6: Experts were more willing to tolerate losses of ACPs they perceived as being lower cost.

Workshop experts therefore tended to favor lower-cost ACPs for the specific reason that they saw it as the only way to maximize capacity in a world of tight budget constraints. It would be far easier to tolerate losses of ACPs with low out-of-pocket unit costs because they were less expensive and therefore more likely to be replaced. Table 6 depicts how experts correlated attritability with cost. The missile TEL hunt team, for example, considered two of their ACPs (ACP 2 and ACP 3) as expendable because they were very-low-cost loitering munitions that did not need landing gear, large fuel loads, air-worthiness certification, or any of the other features required for inhabited aircraft. On the other end of the spectrum, workshop experts considered more complex counterair ACPs (ACP 1 across all three teams) as non-attritable or attritable assets—but not expendable—because they were more expensive and integrated sophisticated radars and carried air-to-air missiles.

Challenge: Autonomy for ACPs is Essential, but its Maturity and Cost are Poorly Understood

A striking observation that emerged from the workshop was the apparent need for very high levels of autonomy, which can be thought of as the ability of a machine to accomplish goals independently, or with minimal supervision, from human operators in environments that are complex or unpredictable.[63] (See Appendix C for the autonomy menu provided to workshop experts).The airbase attack and missile TEL hunt teams, both charged with conducting strikes in a dense threat environment over mainland China, demanded very high levels of autonomy, powered by AI, to rapidly make decisions with little to no human interference. The ACP would need to orient itself in a highly contested environment and make choices in real-time, functions typically thought of as requiring human intelligence.[64] These experts were not interested in tethering ACPs to human operators, although they acknowledged that doing so may be unavoidable in early days given the limitations of current technology and policy concerns about AI and decision-making.

Scientists and engineers involved in the development of AI technology indicated rapid progress, but they were not confident that the AI teams needed for their ACPs would soon be available. The experts also were unsure about the cost characteristics of AI technologies required for ACPs. At issue was the cost of AI software development and licensing agreements, as well as the cost to develop AI-capable computing hardware and integrate it into the ACP. Another concern related to trust in autonomy and ethical issues. There are no domestic or international laws prohibiting the employment of autonomous weapons that can select and engage targets without human control, but experts acknowledged that any autonomy failures could lead to friendly fire incidents, civilian casualties, and wasted resources.

Finding ways to manage uncertainty about AI maturity and cost will be critical because of the need for high levels of autonomy for ACPs operating in communications-degraded and contested environments. Workshop experts wanted ACPs to be able to understand rules of engagement to conduct offensive, defensive, and neutral plays. For example, if given the mission directive to "go look for an SA-21, do not go further than 500 nautical miles, and report back," the ACP would respond by orienting itself in a highly contested and dynamic operating environment and making a series of decisions to complete that task. Such platform-level autonomy was viewed as essential for ACPs to mitigate the need for bomber crews to task ACPs during missions. Without ACP autonomy, bomber crews or humans on the ground would need to control the ACPs, increasing manpower requirements and potentially over-burdening bomber crews in combat. A requirement for bomber crews to provide commands to the ACPs could also put those crews at risk if the communications between the bombers and ACPs revealed the bombers' positions to adversary fighters and air defenses.

In many cases, experts took the autonomy requirement a step further, preferring *collaborative autonomy*. The ACPs would operate independently from human control, but they would communicate with *each other* via difficult-to-detect data links to achieve a pre-determined goal. Experts favored collaborative autonomy in many cases because it would enable the off-boarding of mission systems from bombers to various elements in the ACP force package. This would contribute to the goal of fielding larger numbers of more modest ACPs with disaggregated capabilities. For example, the maritime strike team envisioned ACP 2 (its ISR capability) coordinating with ACP 3 (its strike capability) to synchronize detection, tracking, and engagement of surface combatants.

Workshop participants identified the uncertainty and risk around autonomy as a central challenge for rapid ACP development. They were unsure that the AI for platform autonomy, and specifically collaborative autonomy, was readily available for testing on aircraft, let alone operational use. As one participant put it, "The airframe is not the problem, the low observability is not the problem. The problem is the autonomy and how do they talk to each other and how do they talk to the platform? That doesn't seem to be very developed at all."[65] Experts suggested that one way to manage the uncertainty and risk associated with the development of autonomy might be to pursue open architecture ACP designs that allow for rapid, iterative integration of new software updates to meet evolving operator demands. Post-workshop discussions with Air Force experts suggest that this is indeed their preferred approach, and that early iterations of ACPs will incorporate more modest levels of autonomy that use AI to fully automate takeoff and landing, or fly in a pattern, for example.

Challenge: New ACP Manufacturing Processes Could Increase Production Capacity, but the Concepts are Unproven

Workshop experts also worried about the perilous combination of high combat attrition combined with the Air Force's small, exquisite force structure, which could severely limit the Air Force's ability to replenish aircraft losses. The U.S. industrial base currently lacks the capacity to surge the production of ACPs and munitions to replace combat losses. Decades of lean manufacturing and the lack of major new military aircraft programs means ramping-up ACP production could take many months and even years—well beyond the timeframe they would be needed to sustain operations during a peer conflict within the next decade.[66]

Some experts raised new manufacturing processes as a way to dramatically and rapidly expand and diversify ACP production as well as reduce their costs. Experts cited ACP open architectures as a key advantage that would allow multiple vendors to participate in ACP software development, allowing for more competition and the rapid evolution of software technology.[67]

In discussions with the Mitchell Institute, one senior Air Force leader envisioned the design of smaller and simpler modular ACP platforms that could be produced by many manufacturers in the United States or allied countries with a licensing agreement for ACP design. This would allow the United States and allies to begin armament in peacetime and rapidly surge production capacity in wartime, all while dispersing the risk of attack across a larger number of widely distributed production facilities.[68]

While experts agreed that new manufacturing processes hold promise, it is not clear how quickly they could be adopted. The Air Force Research Laboratory is currently experimenting with new processes that would significantly simplify production. One concept, based on the car industry, involves building single aircraft "chassis" that could then be fitted with different wings, sensors, and payloads, depending on mission requirements. The use of large-scale composites could further reduce complexity and speed production. These ideas imply a radical departure from the acquisition and manufacturing practices employed today. It is unclear whether current DOD and Air Force acquisition frameworks would allow for issuing licenses to a variety of vendors in the United States and abroad, or whether the political will exists in the Pentagon or in industry to support such an initiative.

Conclusion and Recommendations

The Air Force needs a new force design approach to reverse the decline in its warfighting capacity to one commensurate with the demands of the *National Defense Strategy*. As a first principle, it must maintain credible forces of high-end aircraft, including advanced bombers, fighters, and other inhabited and uninhabited aircraft that serve as the backbone of a combat force capable of prevailing in peer conflicts. The Air Force can build on this foundation by developing a family of ACPs that support objectives in the 2022 NDS, including the need for a future U.S. military that is more resilient, risk tolerant, and capable of denial and cost imposition operations to defeat Chinese aggression.

Some of these ACPs could be extremely modest in their capabilities and cost, such as ACPs designed as decoys to complicate an adversary's air defense operations and increase the survivability of other penetrating strike aircraft. Other ACPs designed to perform missions in cooperation with sophisticated inhabited aircraft in highly contested airspace may require more advanced capabilities, like increased autonomy and low observable features. These ACPs can still draw on new technologies and processes to reduce costs, and doing so is essential to ensure the Air Force can acquire them in large numbers to ensure mission success and attrit them if necessary.

Overall, we found that ACPs have the potential to improve the operational effectiveness of the Air Force's most capable combat aircraft in a great power conflict by increasing bomber survivability, creating new options for theater commanders, and improving their ability to generate and sustain combat power by reducing aircrew attrition, dispersing risk, and minimizing C3 vulnerabilities. To rapidly integrate ACPs into its force structure, the Air Force will need to marshal broad-based support and resources. Air Force leaders need to explain how they are embracing innovations in aircraft design, production, operations, and sustainment to move ACPs from the production line to the field. While important activities to advance this agenda may be going on behind closed doors, they must be complemented with plans, investments, and public narratives convincing to OSD, Congress, and the American people that ACP technology can be rapidly fielded, offset force structure shortfalls, and support strategic objectives as outlined in the 2022 NDS. Toward this end, Mitchell Institute offers the following seven recommendations for the Air Force.

Recommendation: Release an Air Force Flight Plan that Links ACP Development to the *National Defense Strategy*

The Air Force should publish an ACP flight plan to support its FY 2024 budget request that: 1) explains why ACPs are an urgent priority, and 2) provides the basis for maintaining a dynamic posture that can adjust ACP integration plans in response to changes in technology and the threat environment.

While the flight plan should build on the ACP Strategic Requirements Document the Air Force recently released to industry, it should also explain how ACPs will support objectives in the 2022 NDS, including their potential to be employed in ways that will impose costs on adversaries.[69] The Air Force's advanced military aircraft are central to any credible strategy to deter and deny China from achieving its campaign objectives, but it is increasingly clear that the Air Force now lacks the capacity for a major conflict with China. A family of lower-cost ACPs could augment its forces and help turn cost-exchange ratios in favor of U.S. joint force operations, giving the United States the ability to sustain combat operations while adversary resources are exhausted. Advantages of an operational force of ACPs include their ability to: 1) increase the survivability of other inhabited and uninhabited aircraft for long-range penetrating strikes and decrease the effectiveness of adversary defenses against them; 2) expand U.S. theater commander options for long-range strike and reduce an adversary's ability to anticipate and respond to multiple, simultaneous attacks; and 3) create war-winning advantages, such as increasing attrition resiliency, distributing risk, and reducing C3 vulnerabilities.

In addition to clearly articulating how ACPs can make a war-winning difference, the flight plan can also provide a sense of how diverse ACP efforts are aligned and indicate timelines for ACP fielding. The goal is to proactively communicate to key stakeholders including lawmakers, DOD, and Congress that the Air Force has a strategy for integrating ACPs. This is important to signal the Air Force understands and is addressing the technical, budgetary, and operational risk involved in ACP development.

An important caveat, however, is that the flight plan should not take on the characteristics of old-style strategic planning, with its focus on trying to forecast a fixed future, building a pre-set plan, and specifying detailed tasks. Given the speed at which ACP technology is changing, this approach could do more harm than good. Rather, the flight plan should strike a balance. It should identify clear, aggressive timelines for ACP fielding, but it also should broadcast the Air Force's intention to maintain a dynamic posture that allows ACP development to respond to rapidly changing threats and technologies. In this spirit, it should outline a few high-level strategic objectives and a vision for a campaign of operational experimentation that is much more focused on assessing changes in the environment and implications for ACP integration in the force rather than box-checking specific tasks.

Recommendation: Launch a Comprehensive Campaign of Operational Experimentation

The immediate objective of the operational experimentation campaign should be to rapidly shore up America's combat capabilities and capacity for peer conflict. In other words, get ACP "rubber on the ramp" as fast as possible by starting a new program of record, then continue experimenting to adapt the technology to warfighter needs. The longer-term goal should be to create the conditions for a decades-spanning effort to evolve the way the Air Force organizes, trains, and equips its forces to the point that it becomes second nature to rapidly, continuously, and frequently field successive generations of ACPs into operational units.

Moving minimum viable products into operational units as soon as possible is important both to allow for adaptation of new ACP concepts and technology and for the rapid enhancement of Air Force deterrence and warfighting capabilities. The Air Force needs a campaign of operational experimentation, endorsed by senior leaders, that fosters new processes, organizations, and norms that emphasize this rapid and iterative approach to updating ACPs across their life cycle. This campaign should have two simultaneous objectives:

1) rapidly fielding ACPs to combat units to meet immediate operational needs; and 2) encouraging risk-taking, data collection and analysis, learning from mistakes, and adjusting quickly as ACP technologies and threats to their operations evolve.

Three key areas of emphasis for this campaign of operational experimentation could be: 1) innovations in flight test processes; 2) the introduction of new experimental units; and 3) collaboration with industry to align incentives.

Flight Test: Air Force flight test regimes now focus on validating technology—not experimenting to improve it—and the use of prototypes in operational units is not common practice. This approach to flight test processes needs to change. Rather than a linear approach to aircraft development, ACP technologies should be adapted in a continuous feedback loop that allows for constant updates in response to changing operational demands and advances in technology. Iterative updates are particularly important for ACPs because of rapid advances in technologies that support autonomy, which can be fielded in increments that gradually improve performance over time.

Experimental Units: Air Force leaders should also consider establishing one or more experimental ACP units that are tailor-made and staffed with personnel able to accommodate rapid ACP software and hardware changes, test those changes, collect data, iterate improvements, and then transition these state-of-the-art ACPs into combat squadrons. These experimental ACP units might be staffed with data scientists, coders, and others with unique knowledge and experience well-suited to supporting operational experimentation. These units could become testbeds for thinking about how to organize, train, and equip combat units with the right mix of personnel and processes so they can continue carrying operational experimentation forward once ACPs are fielded. They also can lead the way in terms of developing tactics, techniques, and procedures, creating early TTP blueprints that operational units can then pick up and improve upon as they test out new ACP technology.

Industry Collaboration: Finally, the Air Force should work closely with industry on its operational experimentation campaign. Prioritizing competition, rapid innovation, and diversity of vendors is a major cultural shift away from the industrial-era processes that still dominate DOD acquisition today. Small production runs and short service life may lead to smaller contracts, reduced aircraft production efficiency, and fewer opportunities for sustainment contracts, but these downsides could be offset by the demand to rapidly build ACPs at scale and more opportunities to expand production into international markets through partnerships or licensing agreements.

A key part of the operational campaign needs to be regular and frequent conversations with industry to better understand the incentives that would drive robust participation in ACP development. In these give-and-take conversations, the Air Force and industry can begin to reconcile tensions between incentivizing creativity and competition while creating a sustainable manufacturing base that can scale to meet operational demands. Maximizing industry collaboration would serve to build trust, level expectations, and increase the odds of coming up with an innovative acquisition solution that breaks with old ways of doing business.

Recommendation: Require ACP Modularity to Enable a Continuous Cycle of Learning, Development, and Production

The Air Force should not "throw away" ACPs that are not optimized for operational demands, but seek to continuously improve their performance through AI software updates. This requires modularity: a standard receptacle in the airframe that can continuously accept new "AI brains" as AI software evolves. The ACP development cycle should also use information and experience gained from operating lead aircraft in new UAV classes to improve the capabilities of follow-on models. And as older ACPs age, it may be possible to use them for different missions, such as adversary air, rather than relegating them to the boneyard.

ACPs designed to plug and play new software—and maybe even hardware—would allow the Air Force to target changes on ACP variants while maintaining their core features over the course of successive updates. It also would improve the potential for multiple vendors to contribute their technological innovations over the aircraft's life cycle. From a software perspective, this modular approach would be particularly important for fielding successive generations of software to improve ACP autonomy. Participants in Mitchell Institute's ACP workshop voiced concerns with the technological maturity of autonomous technologies and identified limitations in the current methods for assessing the costs of autonomy software. ACPs with an open architecture would help enable the Air Force to rapidly test and improve autonomy software, and then integrate it into ACPs that are already on the ramp. The Air Force's AFWERX Autonomy Prime effort, in partnership with industry, is focused on rapidly testing autonomy software and transitioning it to the field. The Air Force should continue that effort and ensure that ACP programs of record have formal requirements for the aircraft to rapidly accept new software as it matures to meet changing operational requirements.

From a hardware perspective, workshop participants stressed the need for new manufacturing processes to reduce ACP production times and increase surge potential. One approach called "platform-sharing" would allow for an ACP chassis to accommodate different structures, sensors, and payloads, much as the auto industry produces different car models from a common baseline chassis. They also cited the potential to exploit digital engineering, which emphasizes digital modeling to experiment with aircraft designs, to rapidly adapt ACP hardware to emerging mission requirements. Industry is already experimenting with digital engineering and other processes to reduce touch labor and the number of parts aircraft require. The Air Force Research Laboratory is also engaged in a series of efforts to examine these new manufacturing processes. Issuing contracts for ACP prototypes might accelerate these efforts. Because industry has an incentive to build aircraft as efficiently as possible, issuing formal fixed-price contracts for small numbers of lower-cost baseline ACPs might help accelerate the evolution in manufacturing approaches.

Recommendation: Complement Ongoing Analysis with Unclassified Workshops and Wargames to refine and demonstrate ACP technologies

The Air Force should use wargames and workshops as venues for the broader DOD community, lawmakers and their staffs, and private sector audiences to improve their understanding of the potential for ACPs to improve the service's operational effectiveness in peer conflicts.

The imperative to keep ACP prices low has been a central theme of public discourse on the development of these next-generation UAVs. While getting on the right side of the cost-exchange ratio with peer adversaries is an important goal, ACPs can offer a variety of other advantages that are far more difficult to quantify in out-of-pocket dollar terms, such as increased inhabited aircraft survivability, diversified and expanded campaign courses of action, and the potential to impose costs on adversaries. From a force design perspective, ACPs should be part of a broader innovative—and potentially revolutionary approach—to rapidly produce combat capabilities at scale and quickly integrate new technologies into existing aircraft. These benefits—not just reduced unit costs—are real advantages that will help the Air Force to compete with China in peacetime and maintain is combat advantage in war.

Wargames and structured workshops that place participants in the shoes of mission commanders to make choices about ACP employment can help them understand their advantages and limitations. The Air Force should conduct these events in venues that would expand stakeholders' understanding of the contribution that ACPs could make in future conflicts. These events would also be opportunities for Air Force and DOD leaders to interact with members of Congress, other DOD organizations, defense industry, venture capital firms, individual inventors, and academics. Many of these experts are doing applied research that could contribute to ACP development, particularly in the field of AI, but they may not have access to the right information. The unclassified Mitchell Institute workshop could serve as a model for ACP stakeholders to engage with key audiences outside the classified world.

Classified wargames and modeling and simulation also should continue to refine ACP requirements and examine ACP advantages in light of the full range of alternative technologies, such as space assets.

Recommendation: Prioritize Fielding ACPs with Modest Capabilities in Larger Numbers; an Initial Fleet Should Include ACPs for Counterair Missions

Insights gleaned from the Mitchell Institute's workshop on ACPs for long-range strike suggest the Air Force should emphasize creating operating concepts that involve employing large numbers of low-cost ACPs in contested environments, particularly for offensive and defense counterair missions.

Air Force leaders have already identified the counterair mission portfolio as a priority focus for ACP development. Secretary Kendall has envisioned a concept that would use up to five ACPs as part of the service's NGAD family-of-systems.[70] Insights developed during this project reinforce the Air Force has serious gaps in counterair capabilities and capacity, particularly for long-range fighter escorts and SEAD. Six out of the nine notional ACP types requested by the operational experts participating in the Mitchell Institute's ACP workshop were targeted at mitigating these gaps, suggesting there is an urgent need for them.

Workshop findings suggest a strong preference for operating concepts that collaboratively use lower-cost counterair ACPs in large numbers. This was seen as an effective approach to complicating an adversary's counter-strike defensive operations and causing air defenses to rapidly expend their weapons, creating opportunities in time for penetrating bombers to strike their targets.

To be sure, large-scale, collaborative ACP operations as part of strike packages could have practical limitations. For instance, bomber aircrews collaborating with ACPs may not have the bandwidth and other means needed to control them in large numbers. Moreover, penetrating stealthy bombers must minimize their communication emissions to avoid detection. To mitigate these limitations, workshop experts preferred using autonomy to help coordinate the collaborative actions of ACPs and minimize the need for stealthy bombers to emit. That said, the current partial maturity of autonomous technologies does not mean the Air Force should avoid developing an initial generation of collaborative ACPs. It does reinforce the importance of building ACPs with open architectures that allow for autonomy software to be updated as it matures alongside new operating concepts for human-machine teaming in contested battlespaces.

Recommendation: Determine Appropriate Cost Assessment Methods for ACPs

DOD, Air Force, and industry experts do not agree on how to assess the costs of ACPs. Some argue that historical cost data from legacy aircraft can be used to estimate ACP costs. Others argue new approaches to aircraft design and manufacturing render that data less useful. The Air Force should use ACP operational experimentation efforts to collect new data to inform assumptions underlying ACP cost assessment.

Low unit costs will continue to be a key feature of any ACP design. But assumptions that ACP costs can be much lower than historic aircraft costs need to be evaluated in light of evidence. Optimists see great potential to dramatically lower costs with new approaches to manufacturing and design, as well as reduced manpower requirements, but the Air Force urgently needs to collect data on real life ACP design, manufacturing, maintenance, manpower, and logistics costs. Air Force operational experimentation efforts can provide an ideal venue to collect data to see if these assumptions bear out.

Getting this new cost data quickly will be critical because it will inform the cost assessment models that are used to shape Air Force choices on ACP acquisition. No cost assessment will be 100 percent accurate—many things can change as an aircraft moves from the design stage to the flight line—but getting reasonable cost estimates will be critical to planning and budget development. Those estimates will inform decisions about the ACP types the Air Force chooses to buy, as well as the size of the ACP inventory.

Recommendation: Diversify Munitions for Penetrating Strikes

The Air Force should develop ACPs within a broader context that considers how munitions might augment striking power and increase survivability of both inhabited and uninhabited aircraft. Operational experts participating in Mitchell Institute's workshop identified a pressing need for more mid-range munitions and large numbers of loitering munitions to augment penetrating strike packages.

The Air Force is developing a family of systems for long-range strike, which will include penetrating bombers, munitions, and possibly ACPs. Workshop experts confirmed there is a critical need for new, mid-range weapons that are sized for internal carriage on bombers. These weapons would have warheads of sufficient size to create effects against hardened and deeply buried targets, and they could be launched at moderate ranges from targets that would increase the survivability of the bombers.

Workshop experts also saw value in incorporating loitering munitions into penetrating strike packages. In some cases, the need to deliver a high volume of fires at a low cost pointed to the need for purely expendable weapon systems. Air-launched loitering munitions proved particularly useful for the missile TEL hunt, which required covering large swathes of highly contested airspace to find dozens of ballistic missile launchers and attrit adversary air defenses. Loitering munitions could potentially play an important role in other scenarios requiring blanket ISR coverage or fast reactions to pop-up threats in highly contested airspace.

Recommendation: Increase Air Force Funding to Create a Future Force Design that Combines ACPs with Next-Generation Manned Combat Aircraft to Conduct Decisive Collaborative Operations

Insufficient funding over the last 30 years caused the Air Force to reduce the size of its forces and cancel and curtail multiple modernization programs. The service now fields the oldest and smallest combat aircraft inventory in its history. Over the next five years the service projects it must divest another 1,463 aircraft and procure only 467 new aircraft of all types due to budget constraints.[71] Reversing this decline will require the Air Force to create a future force design that combines next-generation combat aircraft like the B-21, F-35, and NGAD with ACPs capable of conducting collaborative operations in all threat environments. Realizing the full potential of this force design will require the Air Force to procure these capabilities in sufficient numbers to meet the National Defense Strategy's requirements and operational demands of America's combatant commanders. This will not occur without additional resources—at least 3–5 percent budget growth annually above inflation for a decade or more—for the Air Force.

Final Thoughts

The Air Force is now on the frontier of significant innovations in ACPs that will, when partnered with inhabited aircraft, help address the service's growing capability and capacity gaps. Fielded at scale, ACPs could reduce U.S. attrition rates in peer conflicts while elevating an adversary's costs in blood and treasure for continuing to fight. In this way, the Air Force's adoption of ACPs could become central to a strategy to defeat China's campaign objectives and create the conditions for victory as outlined in the 2022 NDS.

To capitalize on this war-winning potential, the Air Force cannot wait to begin fielding ACPs until it resolves remaining uncertainties about their costs and the maturity of AI that will power them. Rather, the Air Force must accept some technological and budgetary risks to quickly integrate minimum viable ACPs into its operational units where they can be adapted for combat operations. This approach will require new thinking and creative approaches to organizing, training, and equipping the Air Force in the 21st Century, and it demands immediate investments and actions that demonstrate to Congress and other stakeholders that the service is committed to the future of ACPs. In other words, the Air Force must take concrete actions that prove its vision for ACPs is driven by General C.Q. Brown's guidance to "accelerate change or lose," and not the "business-as-usual" practices that have stunted force design efforts across DOD for decades.

Appendix A: Example ACP and Autonomy Development Efforts

This is a partial listing of ongoing DOD and Air Force initiatives associated with developing ACPs and their enabling technologies.

	Organization	Program Name	Purpose
DOD	OSD/Research & Engineering	**MQ-28 Ghost Bat** (OSD/R&E purchased, USAF testing)	Integrate jet-like drones for collaborative autonomy into aircraft squadrons
	Defense Advanced Research Projects Agency (DARPA)	**Air Combat Evolution (ACE)**	Test AI through human-machine collaborative dogfighting
		Gremlins	Program to launch groups of UASs from existing large aircraft such as bombers or transport aircraft—as well as from fighters and other small, fixed-wing platforms—and retrieve them in air with C-130 transport aircraft
	DOD Chief Digital & Artificial Intelligence Office	**Smart Sensor**	Sensor autonomy, DARPA CODE platform autonomy, and non-GPS Position, Navigation, and Timing for Group 5 UAS to enable surveillance and reconnaissance missions without C2 link or GPS
	DOD Strategic Capabilities Office	**Avatar**	AI-enabled platform autonomy framework for UAS to enable crewed-uncrewed teaming for various mission types
Air Force	Air Force Materiel Command	**Collaborative Combat Aircaft (CCA) for Next Generation Air Dominance**	Program oversight for UAS AI and autonomy integration across the USAF
		MQ-Next (Next Generation Multi-Role UAS Family of Systems)	Replace MQ-9 Reaper with family of stealth platforms to conduct counter-air and ISR
	Air Combat Command	**Adversary Air-Unmanned Experimental (ADAIR-UX)**	Nominally for ADAIR-US series aircraft to train pilots, but supporting CCA efforts
	Air Force Research Laboratory	**Offboard Sensing Station**	Inexpensive, modular, attritable aircraft designed for limited service lives measured in years not decades, with limited maintenance
		Skyborg	Develop a platform-agnostic "autonomy core"
		Bandit	Contract award to Blue Force technologies to build four AI-piloted aircraft for ACC's ADAIR-UX
		Golden Horde	Use algorithms & datalinks to allow munitions to coordinate actions without human control
	Air Force Chief Scientist	**VENOM**	Effort to transition DARPA ACE to the USAF, where the program will turn F-16 fighters into AI testbeds for human-machine collaboration in dogfighting

Source: Mitchell Institute

Appendix B: Capability and Capacity Gaps for Penetrating Strike Missions

This appendix provides more detail on each of the capability and capacity gaps identified by workshop participants in their base force packages.

ISR to track moving targets. The ability to track moving targets represented a critical capability and, therefore, capacity gap across all three penetrating strike missions. China will likely employ kinetic weapons, jamming, and cyberattacks early in a campaign to degrade U.S. surveillance assets, communications, and GPS.[72] Even if reconnaissance satellites were available, experts were not confident that the satellites would be able to maintain custody over moving targets. Reasons include a lack of continuous coverage in low earth orbit, uncertainty about the ability of satellites to track moving targets, and competing campaign-level priorities. Lack of assured access to space led experts to consider airborne ISR platforms for their penetrating strike missions, which all required some form of ISR to track moving targets. However, current airborne solutions were found to be lacking.

In the maritime strike vignette, experts resorted to using current-generation ISR aircraft, such as RQ-4 Global Hawk and MQ-Reaper, to track a PLA Navy SAG at stand-off ranges. They worried about the availability and capacity of these assets given the vast expanses of the Indo-Pacific, which make this job difficult. Tracking moving targets was an even worse problem for the TEL hunt and airbase attack vignettes, which required tracking a variety of mobile or relocatable targets deep inside Chinese airspace. Experts were so pessimistic about the survivability of current-generation ISR assets that, rather than try to employ them, they relied on the penetrating strike assets themselves to track mobile targets—a move that dramatically increased the exposure time of those exquisite, inhabited assets to adversary threats.

Command, control, and communications. Given assumptions about China's counter-space, electronic warfare, and cyber activities, experts were very concerned about a lack of access to communications. Connectivity between assets was seen as essential, particularly for developing kill webs that would allow assets to prioritize and deconflict sensing and simultaneous strike missions and to re-task in response to a dynamically changing battlespace, including moving surface and ground targets. In the maritime strike scenario, for example, experts were concerned that it might be difficult to coordinate the tracking of adversary ships moving upwards of 30 knots while controlling many strikers and even more weapons.

Counterair. Experts also identified counterair missions as gaps. For offensive counterair (OCA), these included SEAD, bomber escort, and offensive counterair attack. Defensive counterair, specifically air defense, was another critical gap. These shortfalls, which variously included both capability and capacity gaps, could not be filled by current-generation counterair assets, a finding that reflects the public statements of Air Force leaders.[73] An assumption of the workshop was that the Air Force's NGAD also would not be available, given current production timeline projections.

Defensive counterair. The maritime strike team identified a capacity gap in defensive counterair. Fighter basing was considered less of an issue because the mission was taking place much closer to basing options in Japan, but the team still worried it would not be able to meet its requirement for more than a dozen fifth-generation aircraft to provide a barrier combat air patrol and sensing capability while stealth bombers suppressed SAG air defenses and attacked surface combatants.

SEAD. Of all the counterair mission gaps, the lack of capacity to conduct SEAD deep inside mainland China was one of the most notable. Both the missile TEL hunt and airbase attack vignettes required navigating deep into China's airspace, where stealth bombers might be vulnerable to air defenses. It was not clear that there were even sub-optimal solutions to address this vulnerability. For both the missile TEL hunt and airbase attack teams, a real concern was a lack of reactive SEAD capability, which would be required to target and destroy potentially dozens of TELs and their associated garrisons in the event that Chinese air defenses were able to detect and target stealth bombers. In the 2030 base force, only stealth bombers themselves possessed the adequate range, survivability, and payload capacity required to take out the TELs, but they couldn't be everywhere all at once. As a result, the real issue for SEAD on mainland China was mass; bombers could do the job, but it took big numbers. For airbase attack, experts indicated they would need ten B-21 bombers, with half of that force devoted to reactive SEAD as opposed to the primary strike mission. The airbase attack team also relied on those B-21s to provide an electronic warfare capability for reactive SEAD, since no other assets were available.

SEAD was also a capacity challenge for the maritime strike team. Experts assumed that high-demand, low-density B-21 stealth bombers carrying stand-in attack weapons (SiAW) and miniature air-launched decoys (MALD) would be available to strike HQ-9 air defenses of the surface action group. F-35 and EA-18G Growler aircraft based in the region would be able to support SEAD with jammers, but the EA-18G would not be able to get close enough, and the F-35 would be at risk for strike with SiAW because the requirement to carry it externally would degrade their survivability.

Escort. Experts also struggled to identify available capabilities to escort penetrating bombers over long ranges in highly contested airspace for both the missile TEL hunt and airbase attack missions. Even if stealth fighters were able to take off from bases in southern Japan—despite likely PLA air and missile attacks—experts worried that the distance of the bomber escort mission would exceed the range of those fifth-generation aircraft. For example, experts estimated that the shortest combat radius between southern Japan and the airbase attack targets on mainland China would be about 1,500 nautical miles. Open sources indicate that fifth-generation fighters fall short of that, and experts worried that aerial refueling for the fighters would not be an option because it would risk unacceptable exposure of tankers and fighters to adversary threats.[74]

Strike. For the maritime strike mission, insufficient bomber capacity once again emerged as a significant gap. Experts elected to use the limited inventory of B-21 stealth bombers for stand-in strikes on surface combatants, complemented by B-2s launching long-range anti-ship missiles (LRASM) from stand-off ranges. While stealth fighters were available for jamming air defenses, experts assessed they would be relatively poor candidates for maritime strike because of survivability concerns (i.e., a reduction in survivability caused by signature degradation due to external stores). Experts also decided not to employ the fighters to target surface combatants at stand-off ranges because they lacked sufficient range and payload capacity.

Experts in the missile TEL hunt mission also faced a capacity challenge for its primary mission of attacking over 60 missile TELs in the vicinity of two separate garrisons. Tasked with the objective of reducing ballistic missile launch capacity by 50 percent, the TEL hunt team had to deploy a total of 16 stealth bombers (B-21s and B-2s) for the mission. When one considers that, in 2022, only about 15 bombers total—including both penetrating and non-penetrating assets—would be able engage targets in a single theater at any given time, the requirement for 16 penetrating stealth bombers is very high.[75] Yet, experts were unable to identify viable alternatives that would be able to penetrate deep into China's airspace to find, fix, and finish the missile TELs.

Precision-guided munitions. Across the operational vignettes, experts identified a shortage of munitions and a lack of the right mix of munitions as a serious set of gaps. For the maritime strike vignette, experts were concerned about limited stocks of long-range anti-ship missiles (LRASM). Experts assumed that bombers would execute stand-in strikes with SiAWs in 2030, but fighters would need to draw on the Air Force's small inventory of LRASMs to strike surface combatants from a distance.

For the TEL hunt, experts were concerned that current stand-off munitions like the Joint Air to Surface Strike Missile-Extended Range (JASSM-ER) lacked cueing and target updates that would be required to hit moving and hiding TELs.

For airbase attack, experts worried that short-range munitions like Small Diameter Bombs and the Joint Direct Attack Munition (JDAM) lacked survivability, thereby increasing the risk to inhabited penetrating aircraft by forcing bombers so close to targets that their ability to maneuver to avoid threats was quite limited. Given the assumption of Chinese space and electronic warfare attacks, it may not even be possible for JDAMs to employ their GPS guidance.

Appendix C: Menu of ACP Autonomy Levels Provided to Workshop Experts

Mitchell Institute worked with government experts in autonomy to develop the following descriptions for different UAV autonomy levels. Workshop participants were able to select from this menu when identifying their desired capability attributes for each of their ACP designs.

1. Sensor Perception: Onboard sensors employ automatic target recognition. Sensors flag potential targets to human operator.
2. Multi-Sensor Fusion: Onboard sensors fuse data with off-board information incoming via datalink. The operator sees a fused target picture and can drill down to find data sources as required.
3. Sensor Autonomy: Artificial intelligence/machine learning is controlling physical movement of sensors, slewing them to targets based on automatic target recognition (see #1) and sensor fusion (see #2).
4. Platform Resiliency: If an ACP loses its data link to the human operator and access to GPS, it can still perform its mission with a limited set of trusted onboard behavior and the employment of alternative positioning, navigation, and timing methods to orient itself in its environment and select and (potentially) engage targets.
5. Platform Autonomy:* The platform can intentionally be cut loose from human control to execute a given set of plays, i.e., "go look for SA-21; don't go further than 500 nm, and report back." The platform is capable of understanding rules of engagement to conduct offensive/neutral/defensive plays.
    - 5A. Individual autonomy: A single ACP operates independently of the human operator.
    - 5B. Collaborative autonomy: Multiple uninhabited platforms operate independently of the operator, but they communicate with each other via datalink to achieve a pre-determined goal.

*Note: Platform autonomy means the ACP can only execute missions that the system was previously trained to perform. Determining new types of targets, aircraft signatures, areas of operation, etc., are likely beyond the capability of classic as-trained AI and autonomy.

Endnotes

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24 The Mitchell Institute promised anonymity to workshop participants to increase their candor, so they are not identified by name or organization.

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