MERLIN

Roadmap

Autonomous Flight to Support our Warfighters

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> "If I would have asked people what they wanted, they would have said faster horses."
>
> *—Henry Ford*

1. Introduction

There is broad consensus among experts that the military who dominates the autonomy race will prevail in the Great Power Competition. Both the United States and the People's Republic of China (PRC) – whom Secretary of Defense Lloyd Austin has publicly branded as our "pacing challenge" – are both advancing rapidly[1].

In the realm of air power, experts have pointed to unmanned aircraft and autonomous flight solutions as the way forward. Unfortunately, our strategic approach faces two critical hurdles that must be overcome if we are to maintain a chance at victory.

Dynamic Battlefields

The United States, with its long-standing tradition of innovation and technological prowess, has committed considerable resources to pioneering autonomous flight solutions. However, as we navigate evolving threats and increasingly digital battlefields, it's crucial to honestly assess whether our current trajectory will lead to a demonstrable strategic advantage.

The U.S. military has put forth a number of impressive and commendable preliminary efforts. Most recently, Air Force Secretary Frank Kendall flew in the front seat of a modified F-16 (AI VISTA) as it spent a brief period autonomously performing several tactical maneuvers[2]. On a broader scale, programs like the Collaborative Combat Aircraft (CCA) showcase America's ambition to integrate advanced AI across a multitude of fleets, in part as a means to provide crystal clear demand signals to the defense industrial base that we need to integrate and accelerate.

Meanwhile, the PRC has been rapidly making autonomous flight advancements of their own. A Chinese drone manufacturer recently achieved a major milestone by earning a type certificate and standard airworthiness certificate from the Civil Aviation Administration of China (CAAC) for a commercially available passenger-carrying autonomous aerial vehicle[3]. Additionally, reports suggest substantial investment in military-grade autonomous systems, including integrating narrow AI into unmanned aerial vehicles (UAVs) to transform its battlespace capabilities[4]. Given the well-documented ties between the PRC's government and private sector[5] – and not to mention the brazen scale of its intellectual property theft practices[6] – it can be inferred that the runway for deploying strategically advantageous autonomous flight solutions is short.

[1]https://www.csis.org/analysis/chinas-pursuit-defense-technologies-implications-us-and-multilateral-export-control-and
[2]https://militaryembedded.com/unmanned/sensors/will-the-future-of-the-us-military-aircraft-fleet-be-uncrewed
[3]https://www.electrive.com/2024/02/02/ehang-launches-autonomous-air-taxi-for-300000-euros/
[4]https://dash.harvard.edu/bitstream/handle/1/37373349/202211%20Shirshikova,%20Zhanna%20Thesis%20final.pdf
[5]https://itif.org/publications/2023/01/23/wake-up-america-china-is-overtaking-the-united-states-in-innovation-capacity/
[6]https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/September-October-2020/Tosi-Intellectual-Property-Theft/

Fiscal Realities

The current state of U.S. defense appropriations further complicates the pace at which we can scale and deploy.

U.S. Department of Defense (DoD) budgets, while showing modest growth in recent years, have remained essentially flat in real terms after accounting for inflation. This fiscal constraint poses a significant challenge to the DoD's, and particularly the Air Force's, ability to fund critical modernization efforts across its force structure. Developing and fielding cutting-edge technologies like autonomy and AI requires substantial and sustained investment over an extended period.

Moreover, the U.S. military's adoption of commercial AI has been slowed by regulatory obstacles, ethical considerations regarding opaque AI systems, and difficulties in scaling proven solutions across its enterprise. Recent successes like AI VISTA, while impressive technical demonstrations, have yet to transition from prototype to production, and transformative initiatives like the Collaborative Combat Aircraft (CCA) show great promise but face a long runway—full deployment is years away and carries a hefty price tag. These realities underscore the gap between innovation and operational impact[7].

A Path Forward

Simply put, the competition is innovating at a breakneck pace, and the U.S. lacks the budget flexibility to maintain the lead under traditional frameworks.

To remedy this, the U.S. Air Force must make strategic decisions. Rather than relying on historical budget increases, it must reallocate resources from legacy programs that may be hindering readiness, lethality, and survivability.

We propose a new strategic solution: By leveraging incremental autonomy technologies to reduce crew sizes in transport-class aircraft, the Air Force can affordably implement and scale the next generation warfighting capabilities it needs to maintain its competitive edge.

In the following sections, we present a strategic roadmap: first, by analyzing current aircrew costs; then, by outlining a plan to implement autonomy in transport-class aircraft; finally, by showing how these savings can be leveraged to surpass PRC's advancements.

> "We can never afford enough crewed combat airplanes to sustain a numerical edge [over China]."
>
> *— Secretary of the Air Force, Frank Kendall[8]*

[7]https://airforcetechconnect.org/news/everything-new-we-just-learned-about-collaborative-combat-aircraft-program
[8]https://www.airandspaceforces.com/article/autonomous-armed-and-dangerous/

2. A Better Brand of Autonomy

Technologies that leverage autonomy for single pilot operations are already gaining momentum in the Air Force ecosystem, specifically with transport-class aircraft at Air Mobility Command (AMC) and Air Force Materiel Command (AFMC)[9]. According to multiple reports and tests, this solution set offers a number of technical benefits over those that rely on remote operations:

- **Building Sets and Reps.** Deploying autonomy alongside a human in a traditional flight deck allows the DoD to build hundreds of thousands of hours of trust in autonomy, and gives the system more experience than any human pilot.
- **Fleet Commonality:** Seamless integration of a single pilot capability into a large number of existing airframes, facilitating the continued use of current fleets and weapon systems with a common autonomy core.
- **Operational Independence:** No need for a ground based operator enabling operations in degraded or contested environments, enhancing mission flexibility and survivability.
- **Spectrum Resilience:** Reduced reliance on contested communication channels, minimizing operational risk and ensuring relevance in future battlespaces dominated by electronic warfare.
- **Scalable Deployment:** High adaptability across fixed-wing platforms, expediting fleet-wide implementation once operational benefits are proven.

However, the true value of onboard autonomy transcends technical merits.

A. Reduction of Pilot Training and Lifecycle Costs

While pilots remain the cornerstone of the Air Force, the demands of modern warfare necessitate an evolving force posture. Accordingly, senior Air Force officials have noted the utility of scrutinizing pilot lifecycle costs[10].

As it pertains to the cost of a pilot, there are two primary drivers: initial pilot training and cost to support the full career lifecycle. In total, the combined cost of initial training and full lifecycle support for the Air Force pilot is approximately $16.7 million per active and approximately $10.3 million per reservist. It should be noted that these costs do not include the flying hours needed to maintain proficiency or the costs of operational deployments.

[9]https://www.thedefensepost.com/2024/02/20/kc-135-autonomous-flying/
[10]https://rfpb.defense.gov/Portals/67/Documents/Requiring%20Fully%20Burdened%20Life%20Cycle%20CostsPurposes.pdf?ver=jqaCii5-H-y33Woua-ly1g%3d%3d

For training, initial training costs vary depending on platform, but the average for a new pilot is about $7 million, primarily for flying hours[11]. For the fully burdened lifecycle, the average Airman costs $9.7 million as active duty and $3.3 million as a reservist[12]. These fully burdened costs include overhead beyond compensation, such as military construction and Research, Development, Test, and Evaluation (RDT&E) costs, among others. This is summarized in Figure 1.

Average U.S. Air Force Pilot Training & Lifecycle Costs	
Training	$7.0 million
Active Duty Cycle	$9.7 million
Reservist Lifecycle	$3.3 million
Total Costs for a Active Duty Pilot	$16.7 million
Total Costs for a Reservist Pilot	$10.3 million

Figure 1: Average U.S. Air Force Pilot Training & Lifecycle Costs

Source: RAND Corporation and Reserve Forces Policy Board Reports

While these costs provide a rough estimate, they likely understate the full costs to the Air Force for multiple reasons:

- **Deployments:** Estimates assume a single deployment over a 20-year career for both active and reserve personnel; additional deployments would increase costs, especially for reservists.
- **Modern Proficiency:** Estimates do not include ongoing training costs to maintain pilot proficiency, which would be lessened after integration of an onboard autonomy system.
- **Retention Bonuses:** Estimates do not include bonuses needed to retain pilots, which have swelled to up to $600,000 per pilot (paid over several years).
- **Inflation:** Estimates were conducted in 2019 and do not account for inflation.

Reducing pilot accessions would lead to immediate cost savings, primarily in operations and maintenance (O&M) training accounts, due to the upfront nature of initial pilot training expenses.

[11]https://www.rand.org/pubs/research_reports/RR2415.html?adbsc=social_20190327_2733701&adbid=1110924217778790401&adbpl=tw&adbpr=22545453
[12]https://rfpb.defense.gov/Portals/67/Documents/Requiring%20Fully%20Burdened%20Life%20Cycle%20CostsPurposes.pdf?ver=jqaCii5-H-y33Woua-ly1g%3d%3d

More significant savings would come over time due to the reduced number of pilots in the force structure.

Based on the analysis below, reducing the pilot accession requirement by 500 slots would save the Air Force almost $6 billion in initial training and lifecycle costs. Figure 2 shows the savings associated with reduced pilot requirements at varying levels from 500 up to the 2,000-pilot shortfall.

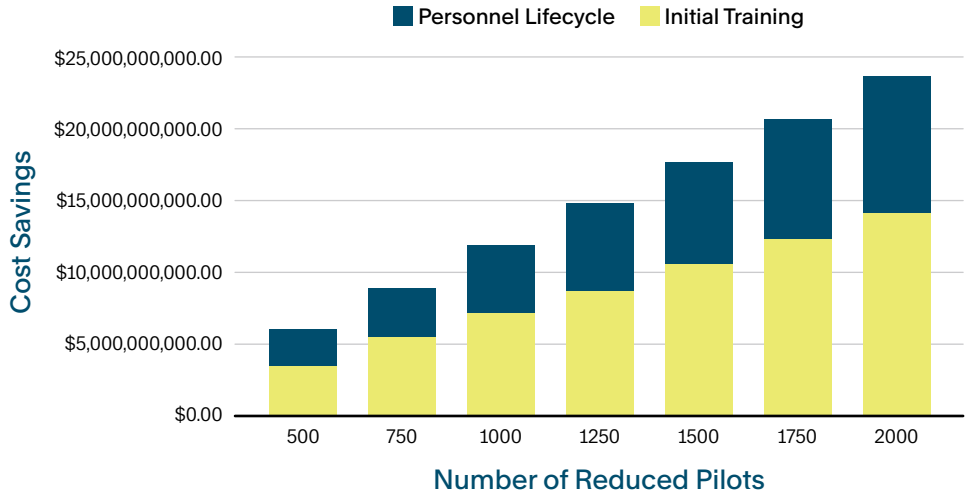

Figure 2: Initial Training and Personnel Lifecycle Savings Associated with Reduced Pilot Requirements

Note: Initial training costs are averaged across the fleet as shown in Figure 1 and assumed to be equal for active and reserves. Lifecycle savings projections assume equal numbers of active and reservist slots would be reduced. Note: Initial training costs are averaged across the fleet as shown in Figure 1 and assumed to be equal for active and reserves. Lifecycle savings projections assume equal numbers of active and reservist slots would be reduced.

B. Force Structure Flexibility

Reducing crew sizes through autonomy offers additional benefits beyond lowering pilot accession requirements; it presents an opportunity to reshape the Air Force's pilot force structure. While the exact reduction in pilot needs depends on the specific integration model, initial projects suggest a potential halving of pilot crew size – a capability yet to be fully demonstrated.

Furthermore, integrating autonomous solutions to assist pilots can potentially extend the service life of deployed platforms. With fewer pilots requiring training hours, there's a corresponding decrease in wear-and-tear on aircraft and equipment. It can therefore address the pilot shortage while simultaneously extending aircraft lifespans.

Additionally, while current pilot accession difficulties have necessitated increased retention bonuses to manage shortfalls, this has resulted in a more senior force. This may not be ideal long-term, especially as mission profiles evolve.

From a budgetary standpoint, allowing senior pilots to retire would eliminate significant retention bonus costs. Their compensation would shift to the military retirement program, freeing up currently allocated personnel funding. While the exact savings are subject to several variables, estimates suggest an active Lieutenant Colonel (O-5) pilot incurs a fully burdened cost exceeding $340,000 annually (excluding retention bonuses)[13], a figure from 2018, which has likely ballooned from inflation.

This approach optimizes the pilot force structure by reducing reliance on high-cost, senior personnel while fostering a more agile and adaptable force to address future mission requirements.

C. Improved Training

Pilot shortages and low aircraft mission availability rates have hampered the Air Force's ability to execute its flying hour program in recent years. Consequently, pilot training hours have fallen below target levels, impacting readiness.

Incremental autonomy solutions that rely on one pilot offer a solution for two-pilot aircraft like the C-130 and KC-135. They introduce greater training flexibility. While some pilot training would be required to learn these systems, training missions could be conducted with a single pilot, mitigating the impact of pilot availability. Training sorties could also involve two pilots alongside the onboard autonomy system, maximizing training value per sortie and reducing overall aircraft wear-and-tear.

In essence, this path forward for maximized training time with minimized total flying hours. This directly addresses pilot readiness concerns by ensuring critical training objectives are met despite potential personnel shortfalls.

D. Improved Readiness

One area yet to be further explored is the downstream readiness benefits to the scaled implementation of single-pilot autonomous solutions. For the purposes of this exercise, there are two examples to consider in the immediate term:

- **Cognitive Load:** Following initial training, onboard autonomous solutions could demonstrably reduce pilot cognitive load. By assuming routine flight operations, the autonomy frees pilots to focus on high-level tasks demanding human judgment and criticality in contested environments. This expanded "mental bandwidth" unlocks the potential for additional missions without requiring increased crew size, maximizing operational flexibility and effectiveness.
- **Maintenance:** With an Operations and Maintenance (O&M) budget of $76.5 billion in Fiscal Year 2025[14], the Air Force is actively seeking ways to reduce maintenance and sustainment costs. Fewer pilots needing training translates into decreased wear-and-tear on aircraft and equipment, decreasing their sustainment cycles and increasing their deployment time. This approach not only addresses personnel challenges but also extends the lifespans of existing aircraft simultaneously.

[13]https://rfpb.defense.gov/Portals/67/Documents/Requiring%20Fully%20Burdened%20Life%20Cycle%20CostsPurposes.pdf?ver=jqaCii5-H-y33Woua-Iy1g%3d%3d
[14]https://www.saffm.hq.af.mil/FM-Resources/Budget/#:~:text=The%20U.S.%20Air%20Force%20FY%202025%20budget,increase%20from%20the%20FY%20 2024%20budget%20request.

Conclusion

Reducing crew sizes through incremental autonomy represents a transformative opportunity for the U.S. Air Force. By replacing up to one pilot in multi-pilot aircraft with an autonomous system, the Air Force can realize tremendous savings in pilot training and personnel lifecycle costs. Reducing pilot requirements by just 500 could save nearly $6 billion. Over time, this path allows the Air Force to reshape its pilot force structure, retiring senior personnel and associated high retention costs in favor of a younger, more adaptable force.

Beyond the fiscal benefits, these solutions introduce greater flexibility for pilot training by enabling single-pilot sorties. It also has the potential to improve overall readiness by reducing pilot workload and cognitive burden during routine operations, freeing up mental bandwidth for critical tasks.

In an era of evolving threats and constrained budgets, this path forward stands out as a cost-effective solution that simultaneously addresses the multi-faceted pilot crisis and generates substantial cost savings. It provides a pragmatic path to modernize force capabilities while operating within fiscal limitations. The value proposition of single pilot operations is clear – it serves as a true force multiplier to elevate Air Force effectiveness and affordability for decades to come.

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