



# **A Cost-Benefit Analysis of Pilot Training Next**

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Talon M. Pope, Captain, USAF  
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DEPARTMENT OF THE AIR FORCE  
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**A COST-BENEFIT ANALYSIS OF PILOT TRAINING NEXT**

**THESIS**

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In Partial Fulfillment of the Requirements for the  
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**Captain, USAF**

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# **A COST-BENEFIT ANALYSIS OF PILOT TRAINING NEXT**

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### **Abstract**

The United States Air Force (USAF) is currently facing a 2,400-pilot shortage in an increasingly constrained budgetary environment. Without pilots to engage the enemy, deliver weapons, and provide logistics support for operations, the USAF could lose the ability to fly, fight, and win global engagements and defend the homeland. This study focused on Undergraduate Pilot Training (UPT) as a means of producing the USAF's pilots to offset the current shortage. Specifically, this study compared UPT to the recently initiated Pilot Training-Next (PTN) program through a cost-benefit analysis. Like any new technology integration, PTN's virtual reality training will require further study for proofing and justification prior to full-scale implementation and further utilization of constrained USAF resources. This study's use of extant financial and historical production data, coupled with interviews with PTN instructors, highlights the potential of PTN. Ultimately, this study's cost-benefit analysis uniquely contributes to the growing body of virtual reality training research through a *Formula for Change* theoretical lens, while simultaneously providing USAF decision makers a comparison of program *costs*, projected *production* capacity, and *quality* of training.

*To my family; for the horde.*

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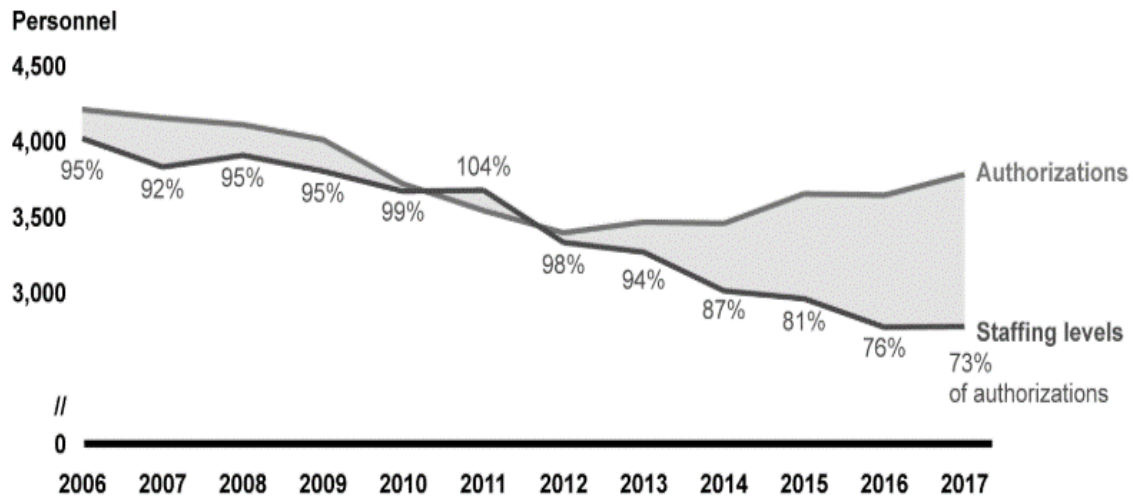
# A COST-BENEFIT ANALYSIS OF PILOT TRAINING NEXT

## I. Introduction

### Motivation & Background

The United States Air Force (USAF) is currently facing a 2,400-pilot shortage [1] in an increasingly constrained budgetary environment [2], [3]. Without pilots to engage the enemy, deliver weapons, and provide logistics support for operations, the USAF could lose the ability to fly, fight, and win global engagements and defend our homeland [4], [5].

The USAF is no stranger to pilot shortages [6] and the current shortage is no less dire than its predecessors. According to the Government Accountability Office (GAO), the current shortage affects many pilot communities (e.g., fighter, bomber, and special operations pilots) and extends to other Department of Defense (DoD) agencies [5]. As the pilot community with the worst shortage, each USAF fighter pilot represents a substantial investment to the USAF with a cost-to-train between \$3 and \$11 million over five years [5]. Staffing and personnel moves are handled within each career field, but not having enough personnel to call upon severely limits flexibility in assigning the best qualified candidate to each authorization [7]. Since 2012, the number of fully trained, mission-ready fighter pilots filling critical positions (staffing levels) has dropped precipitously below the total available positions (authorizations) as shown by Figure 1. For example, in 2017, less than 3,000 fighter pilots filled congressionally-allocated positions (including staff, training, and flying positions), representing a 27% gap between authorized and staffed positions; this trend is expected to continue past the year 2030 [5].



Source: GAO-18-113 [5]

Figure 1: Current Fighter Pilot Shortage, Authorizations vs Staffing Levels [5]

According to Lt. Gen. Gina Grosso, the Air Force Manpower, Personnel and Services Deputy Chief of Staff, the USAF’s plan to fix the current pilot shortage concentrates on evaluating three paths: reducing demand for pilots in non-flying positions, increasing retention of current pilots and increasing the number of new pilots produced through training [8]. To date, the USAF has explored the following methods to fix the shortage:

- 1) pilot retention bonuses [9], [10],
- 2) voluntary return to active duty from retirement [8], [11], [12],
- 3) pilot life-improvement programs [12], [13],
- 4) personality testing as a prognosticator for airmanship skills [14], [15],
- 5) the feasibility of fly-only pilot tracks [16],
- 6) a warrant officer track [17], [18] and
- 7) the inclusion of enlisted aviators [19], [20].

Many of the explored methods have skewed heavily toward retention or getting existing pilots back to flying, leaving increased training production relatively unexplored. This is likely due to increased pilot production’s unique challenges including the increased number of required aircraft, amplified instructor availability constraints, and

support functions and resource limitations (e.g. maintenance, facilities, infrastructure, and auxiliary services) [21]–[23]. If the current aircraft inventory cannot cope with the increased demand, the USAF would also need to overcome the rising cost and complexity associated with procuring additional aircraft [24], [25]. Assuming more aircraft could be acquired, the USAF still requires qualified training instructors sourced from already strained staff and flying positions [8]. These potential instructors must continually be won over from the enticing offers to fly with commercial airlines [26], [27].

Consequently, two key questions emerge: 1) Is there a way to train more pilots without obtaining additional aircraft and support equipment? 2) Is there a way to train more pilots without increasing the strain caused by drawing instructors from critical positions?

Fortunately, the USAF has already discovered the principal components of a solution. This solution comes in the form of emerging technologies that improve existing simulation capabilities. Historically, the USAF’s technology adoption was constrained by expensive initial and recurring sustainment costs that ultimately limited total availability [28]. Despite these constraints, the USAF has depended upon simulators for decades “to reduce costs, extend aircraft life, maintain flying proficiency, and provide more effective training, especially in areas difficult to train in operational aircraft [29:ii].” However, with the expansion of virtual reality for educational purposes [30]–[32] and recent surges in hardware and software proliferation, costs for virtual reality training have fallen dramatically as the technology becomes more mainstream [33], [34]. This means virtual reality now presents an excellent alternative to traditional USAF simulators by providing a realistic training experience at a lower cost [35].

## **Research Gap**

Perhaps fortuitously, the current USAF pilot shortage arose concurrently with the rapid expansion of virtual reality training capabilities. Unfortunately, despite support for virtual reality training's growing utility at a reduced cost, this change in thinking also exposes a dearth of extant research specifically related to USAF pilot training. To be effective, virtual reality pilot training must simulate the real world as accurately as possible to ensure the highest transfer of training and pilot safety [36]. This is necessary because a USAF pilot's job is dynamic and involves coordination and cooperation between multiple individuals to achieve a successful sortie [37]. Previous studies have employed innovative equipment and extolled virtual reality's immersive environment for training, yet no study has examined a virtual reality training environment sufficiently complex enough to replace portions of USAF pilot training (e.g., the ability to replicate realistic data-intensive task management and situational awareness scenarios while monitoring multiple pilots' complex cognitive loads [38]–[40]). Furthermore, no studies have addressed the costs and benefits of virtual reality training as a means of overcoming organizational resistance to adopting the technology.

## **Research Purpose**

This study focuses on Undergraduate Pilot Training (UPT) administered by the USAF's Air Education and Training Command (AETC) and compares UPT's *cost*, *production*, and *quality* to the recently initiated Pilot Training-Next (PTN) program through a cost-benefit analysis. A cost-benefit analysis was chosen because it compares current and new approaches by offering “a unique opportunity to transform legacy defense forces into efficient, effective, and accountable 21<sup>st</sup>-century organizations [2:1].”

The initial budget and format of PTN suggest that this new approach could represent a cheaper, faster and more flexible way to increase the number of trained USAF pilots to offset the current shortage [41]. While PTN explores many areas of pilot training innovation, this study focused specifically on PTN's utilization of virtual reality training. The first iteration of PTN employed virtual reality training in place of some training flights, thus reducing the number of required flights in actual training aircraft. Additionally, with the increased modularity and portability of the PTN setup, each instructor retained greater ability to train more than one student at a time, directly improving those students' flying skills. Like any new technology integration, PTN's virtual reality training will require further study for proofing and justification prior to full-scale implementation and additional utilization of constrained USAF resources [42], [43].

This study's cost-benefit analysis will uniquely contribute to the growing body of virtual reality training research through a *Formula for Change* theoretical lens, while simultaneously providing USAF decision makers a comparison of program *costs*, projected *production* capacity, and *quality* of training. To achieve this, the cost investigation centers on assessing and comparing PTN's initial, fixed, and variable costs to UPT's respective costs. Next, PTN's impact to USAF mission-ready pilot availability, via optimized aircraft and instructor utilization, illustrates how quickly full implementation of PTN—provided current support levels—could heal the current pilot shortage. Finally, this study's quality investigation establishes context and comparison of quality between PTN and UPT pilots.

## II. Literature Review

This literature review contains five main sections. The first section begins with some formative military and civilian virtual reality training research to reinforce the scope and significance of this study. In the next section, the *Formula for Change*, as a theoretical framework, restructures the complex nature and outcomes of pilot training via meaningful ‘lenses’ for analysis [44], [45]. After theory, the last three sections discuss the components of the cost-benefit analysis. This study compares the *cost*, *production* capacity, and *quality* of pilots, through the *Formula for Change* lens to provide the appropriate background for the reader to understand the literature in this domain of research.

### Virtual Reality Training

Virtual reality’s flexibility, low cost, and popularity have not escaped the attention of the USAF and the military industrial complex, especially for realizing virtual reality’s potential for training. As far back as 1991, the USAF Human Resources Directorate’s Intelligent Training Branch began studying the utility and preliminary applications of virtual reality training for relatively simple spatial, navigational, and sequential tasks. Despite using rudimentary virtual reality technology, the study found that students who trained with virtual reality showed increased knowledge retention, faster acclimation over multiple training iterations, and superior task performance when compared to a statistically-generated random benchmark [46]. Following that study, the North Atlantic Treaty Organization (NATO) held a conference focused on applying virtual reality training to more complex tasks including “systems for dismounted combatants, mission rehearsal for special operations, training ship handling skills, tele-

robotics, and practicing military medical procedures [36:iii].” Ultimately, these subject matter experts recommended focusing on military-specific virtual reality training to overcome human factors obstacles (e.g., haptics, user interfaces, stimulation methods) while increasing user response accuracy and decreasing cyber sickness [47].

Military research is not the only source of studies aimed at validating virtual reality training as a means of improving student task proficiency and refining system scalability from a managerial standpoint [48]. In 2002, a randomized, double-blinded specialized medical study found virtual reality-trained students performed their tasks 29% faster than non-virtual reality-trained students [49]. Additionally, these students made six times fewer errors and nine times fewer failure-to-progress indications [49]. The same study identified a need for greater focus on increased transfer-of-training from virtual success to operational success to enable a pathway to more sophisticated uses of virtual reality (e.g., assessments, training, error reduction, and certifications) [49]. Similarly, a successful 2016 virtual reality-based training study created for non-military drone pilots highlighted the difficulty of modeling non-linear, three-dimensional problem-solving environments, the need for improvement in physics models for realism, and additional external validation [50].

## **Theory**

The original *Formula for Change* was attributed to David Gleicher who created the formula as a framework for solving complex organizational problems [51], [52]. The formula was reframed by Kathleen Dannemiller who sought to integrate organizational buy-in with technological innovation to connect organizations to their desired outcomes in a simple, understandable format [52], [53].

Taking Gleicher’s utilitarian problem-solving tool and applying Dannemiller’s mnemonic style, this study developed the model shown in Figure 2. This figure demonstrates the relationship and implications of the following components as they relate to this study: virtual reality pilot training represents a possible end-state or change; USAF guidance and community buy-in for that change represent the shared vision; PTN represents an innovative first step toward the change; motivation captures the dissatisfaction with the status quo and desire to achieve the change; resistance captures any residual hindrance to attaining the change.



Figure 2: Modified Formula for Change Component Breakout

Stepping through each of the components, the modified *Formula for Change* model assumes change begins with shared vision. Shared vision encapsulates the concepts of leadership and member awareness of an issue, a clearly defined end-state, and a path toward that desired end-state [45], [54]. In this case, the USAF’s shared vision requires cost effective spending and rapid acquisition of innovation [4], [55] to overcome the current pilot shortage. This vision provides guidance for execution of innovation and the application of motivation to collectively overcome resistance.

Innovation consists of the first actions necessary to get to the desired end-state (e.g., leveraging technology, adopting best practices, and restructuring the organization). For technology to constitute innovation in this model, the technology must be real and

applicable to the end-state. If the technology is only theoretical or lacks utility to reach the end-state, increased motivation may be required to improve and apply the innovation to overcome resistance. Initially, innovation is binary for this model, the focus is determining whether action occurs or not, instead of identifying the effectiveness of that innovation. Yet, the long-term effectiveness is still important, especially when considering validation is necessary to sustain motivation. Often innovation comes at a high initial cost, with quantifiable benefits realized many years later; this is where a cost-benefit analysis provides context and quantifiably demonstrates strengths and weaknesses of the innovation compared to the status quo [2].

Motivation includes both dissatisfaction with the status quo and proximity to the change compared to the costs of getting to that desired end-state [56]. Proximity represents the gap between the issue and the end-state. If that gap is too large, motivation can decline if not countered by a high dissatisfaction with the status quo [45]. For this scenario, the benefits of attaining and sustaining virtual reality training are just beginning to surface, however for PTN to succeed, these benefits must positively outweigh the costs (e.g., capital, time, risk) to perpetuate motivation.

The previous components must be present, in sufficient quantity, and function collaboratively to overcome resistance. An important intuition of the modified *Formula for Change* model comes from this compound structure that indicates that if any of the change components (left-side, green arrows) are missing or zero, resistance (right-side, red arrow) could prevent the change. This is because resistance to change is rarely, if ever, zero [52]. Assuming the reduction of resistance to the change cannot occur by force, and neither the dissatisfaction with the current pilot shortage nor USAF's vision and resolve to fix it are likely to diminish, PTN's success remains the only component

open for modulation and assessment. To measure and validate this success, this research focused on three areas: *cost*, *production*, and *quality* to substantiate a cost-benefit analysis.

## **Cost**

Cost estimation and forecasting research is as diverse and varied as the many projects and applications that depend on such calculations [2], [57]. Regardless of any assumptions made to develop a cost comparison, all calculations must adhere to generally accepted principals of accounting for validity [58], and be grounded in units that make sense to data consumers—in this case, USAF decision makers [59]. Historically, the USAF has overcome resistance to adoption of increasing fidelity training devices by demonstrating that flight simulators cost less than real aircraft--both in training time savings and when acquisition cost-per-unit are amortized over the life of the system [28]. Contemporary research also supports lowering total cost-per-pilot by capitalizing on virtual reality with the added benefit of improving the realism, scalability and flexibility of military training [38], [47], [60]. Unfortunately, virtual reality training has not yet reached a steady state, a condition that severely limits the accuracy and utility of life-cycle cost projections [61], [62]. To counter this predicament, previous research has focused on a variable cost-per-pilot as a metric for comparing simulator-based training to aircraft-only methods [63].

## **Production**

Another form of organizational resistance stems from comfort with the current process and fear of the unknown when making significant changes [45]. Currently, the USAF trains pilots on a rigid timeline wherein student pilots are introduced to flight

concepts and then tested via evaluation flights, steadily increasing pilot proficiency and complexity [23]. To standardize flying proficiency the USAF begins formal flight training with UPT. This training includes ground school for basic airmanship, simulation training, and actual flights in real aircraft. UPT uses the T-6 Texan II for the first phase of training, then separates students into more specialized tracks. These training tracks utilize more complex training aircraft including the T-1 Jayhawk for mobility pilots and the T-38 Talon for fighter pilots. Pilots then attend dedicated aircraft training at a Formal Training Unit (FTU). This training, coupled with additional time at their operational base allows for certification as mission-ready pilots in their respective Mission Design Series (MDS), otherwise known as their primary aircraft. Each phase of this training pipeline requires time, aircraft, instructors, and supporting resources. Therefore, any change to this production process has long-reaching implications and contributes to organizational resistance to changing the current process [23].

A way to overcome this resistance to organizational change is to get leadership and member buy-in [45]. The USAF leadership recently implored Airmen to solve complex issues (like the pilot shortage) by leveraging the best of technology and industry innovation [4], [55]. Simulator training is an example of this civilian innovation, and is now accepted as an integral part of the processes of civilian pilot training [64]. Even the Federal Aviation Administration (FAA)—the regulatory oversight for many of the USAF’s main competitors for retaining highly-skilled pilots [10]—now permits up to 100% replacement of initial and recurring training and evaluations on simulators instead of aircraft, assuming minimum simulator capabilities and functionality [65].

Additional USAF member buy-in can be generated by allowing members to feel empowered by innovation and proximity to the success of the initial PTN pilots [45].

Opportunity to be part of the change could come through implementing and absorbing the continuing advances in computer hardware, software and peripheral devices that enable virtual reality's leverage as a training device to engage human senses to a greater degree than legacy simulators at a lower cost [60]. Perhaps some members, especially instructors seeking a reason to stay in the USAF, would find empowerment via virtual training's capacity for greater instructor engagement that, in turn, leads to better transfer of training and, potentially, better pilots [66], [67]. Others may find motivation in virtual reality training's reduced instructor workload, and the subsequent decreased wear on training airframes [23]. Finally, virtual reality training's reduced implementation timeframe and technology refreshment cycles, following Moore's Law, combine to allow for more rapid change and upgrade cycles compared to previous technology [68]. This enables untold flexibility and adaptability as a skills-teaching tool [60] that correlates to higher job satisfaction for instructor pilots.

The implementation of PTN is the USAF's innovative first step to reducing the pilot shortage. PTN incorporates virtual reality headsets and high-fidelity physical training equipment with tactile, audio, and haptic feedback. These features, accentuated by instructors and artificial intelligence, provide training scenarios as close to realistic flight as possible. Students engage this training unbound by UPT's lockstep pass-or-fail timeline. Instead PTN encourages exploration at each individual's learning level, both during on-duty and off-duty hours. Available aircraft or simulator support limitations no longer constrain training. Instead, student pilots have more opportunities to train: virtually in their dorms, cooperatively with peers, and with instructors in realistic scenarios to further hone their skills.

## **Quality**

Possessing initial levels of vision, innovation, and motivation may not be enough to overcome resistance to change [45]. To overcome resistance and sustain the change, each of these components must actively support and reinforce the others. Stated another way: to ensure maximum motivation, vision must drive the innovation. Innovation then must prove at least partially successful to maintain momentum and the enthusiasm that transforms the innovation into the new status quo, the desired end-state [45].

For PTN's innovation to become accepted as the new status quo for pilot training throughout the USAF pilot community, PTN graduates must be the same or better quality when compared to their peers [69]. All the cost savings, production optimization, and increased realistic virtual experience would be meaningless if the PTN pilots do not perform at an equitable level as their UPT peers. If unchecked, this condition opens PTN to reduced acceptance and motivation, and greater negativity toward the change. This would further fuel organizational resistance and potentially prevent the USAF's change from UPT to PTN.

This is not the first study to assess the quality of pilot training across competing programs. Previous USAF simulator upgrades have demonstrated that improved flight training devices positively correlated to a greater transfer of training and increased student pilot skill retention when compared to legacy training [70]. More recently, a comprehensive 2003 study found that virtual reality training improved productivity and flight experience especially in areas of critical factor recognition, decision-making skills, situational awareness, and crew coordination [71]. These findings were reinforced by studies that concluded that the retention of skills taught in a virtual reality environment were based primarily on equipment fidelity, realism, and integration of available

technology [72], [73]. A corollary study found little to no difference between the fidelity of simulators used for training--beyond a defined minimum requirement--when measuring the quality of training via regression [74]. However, that same study indicated a marked improvement in flying task performance by simulation-trained pilots versus a control group who received no simulator training.

As an important caveat for quality measurement, one study found a positive correlation between a student's interest in a specific technology with their ultimate retention of skills taught using that technology [75]. Another study conducted between online and in-residence (non-pilot) students concluded that overall performance, quantified by grades, was chiefly dependent upon each student's motivation and ability to self-regulate learning [76]. Together, these studies indicate that each student's receptivity to the training method and individual motivation likely bears consequence upon overall performance and corresponding scores.

### III. Methodology

This study employed multiple data collection methods including qualitative telecommunication and in-person interviews with subject matter and data experts. A site visit focused on collecting production and financial information in addition to interviewing PTN leadership to gain content for the qualitative analysis. The following sections detail the information sources, assumptions, limitations, and approaches used to establish this study's *cost*, *production*, and *quality* analysis.

#### Cost

Cost estimation and analysis require standardized data collection to substantiate cost-effectiveness between alternative flight training programs [28]. For consistency, this research's cost data was derived from AFI 65-503 (Tables A34-1, A34-2 and A4-1) [77], AETC's Financial Management official records (derived from Air Force Total Ownership Cost (AFTOC) data), and UPT historical production data provided by the Air Force Personnel Center Headquarters Strategic Research and Assessments Branch. This research utilized the following syllabi as they represent the highest total USAF capital and personnel investment: Sheppard Air Force Base's USAF Euro-NATO Jet Pilot Training syllabi for T-6 and T-38 (P-V4A-N and P-V4A-N[T-38C], respectively) and Laughlin Air Force Base's T-1 syllabus (P-V4A-G). Additionally, as PTN is under development, it lacks robust historical financial programming comparable to UPT; therefore, fiscal year 2018 budget allocations and student grade sheets from the first iteration comprise this research's PTN financial underpinnings.

Following accepted methods for conducting a cost-benefit analysis [2], [59] and in adherence to AFI 65-503 costing and government accepted accounting practices [57]

the total cost-per-pilot for each program was chosen as the key comparison metric. This research utilized flying and logistics costs broken out per hour, per airframe. Those costs, multiplied against each representative syllabus' hourly requirements, provide UPT's total and variable cost as a benchmark to compare against PTN's initial, fixed, and variable cost. Additionally, Moore's Law was integral to this study's cost assumptions for technological development timing, and provided the two-year aviation-based system replacement cycle necessary for forecasting programmatic costs [68].

## **Production**

When performing production forecasting as part of a cost-benefit analysis, research must focus on comparable attributes of both programs and to highlight the limiting factors for each [2], [57]. This research calculated production capabilities for both UPT and PTN using the previously described documentation and focused on production of Combat Air Force (CAF) and Mobility Air Force (MAF) pilots as both UPT and PTN produce these pilot-tracks. This research discovered the production limiting factors via interviews with subject matter experts.

After establishing the context of production restrictions, research moved to comparative projections of total pilot output through iterative optimization. This analysis, predicated on Little's Law, considered the change in arrival of inventory (student pilots through each phase of training) and reduction of delays to determine overall output to return a metric encompassing the USAF's total usable time of fully-trained, mission-ready pilots. Additionally, Little's Law grounded student pilot inventory and delay-induced bottleneck calculations [62] that were then used to compare this

study's iterative improvements over a ten-year notional period. The ten-year period helps illustrate each optimization's efficacy against the pilot shortage.

## **Quality**

As is often the case with cost-benefit analysis, a nascent system like PTN may not have sufficient data for fruitful comparison [2] especially in the first iteration. This study proved no exception. Great effort went into collecting data to compare the PTN students' grades to a normalized evaluation score baseline—derived from G-TIMS, a database that tracks a multitude of pilot training metrics, including evaluation scores—however that data proved to be unattainable in the timeframe allotted for this research. Additionally, given the time between PTN completion and the wait time to enter FTU, a follow-up comparison with the PTN students to their FTU peers proved difficult as only a few PTN graduates had entered FTU courses. During this study, no PTN graduates had completed their full training profile to produce comparable scores. Understandably, agents responsible for those courses could not release information until graduation without unduly influencing the outcome or otherwise skewing the results [80].

However, the majority of this research's usable pilot quality comparison stemmed from the data gathering research trip and interviews with instructor pilots involved in PTN. Individual and group interviews were conducted to gather information on perceived attributes considered critical to performance. The term 'attribute' refers to the inherent cognitive aptitudes and personality traits that must be present to acquire the level of knowledge and skills needed to successfully operate as, and adapt to, the unique demands of a USAF pilot. The interviews included a review of PTN's unique operations, the stressors and job requirements associated with pilot duties, and how students compare

to former UPT students. Discussion also entailed a review of cognitive aptitude and personality traits perceived as critical to adapting and thriving during PTN.

In addition to providing context and a better understanding of PTN, the instructor pilots provided credible observations of the PTN students' performance and a comparison to their previous (legacy UPT and FTU) students. It is important to note that the PTN program recruited experienced instructor pilots from various legacy training platforms. These include T-6 and T-38 instructor pilots and combat-proven mission ready pilots from other primary weapons systems. Collectively, the instructor pilots provide PTN students a comprehensive breadth of USAF aviation expertise that adds realism and accuracy to the training experience.

#### IV. Analysis

This analysis section details the *cost*, *production*, and *quality* components of this study's cost-benefit analysis. The cost analysis utilizes graduate track ratios and published financial information to compare PTN to UPT based on initial, fixed, and variable costs. For production, historical UPT annual averages and aircraft utilization ratios fortify each iterative increase in the USAF's available pilots, based on incremental optimization of wait-time reduction and application of PTN innovation across the pilot training process. To add context, these optimizations—mapped over a notional ten-year period—further delineate their respective impact to the current pilot shortage. Finally, insight gleaned from PTN grade sheets and interviews with instructors comprises this study's quality analysis.

##### **Cost**

Utilizing historical UPT production data and PTN grade sheets, each program's graduates, sorted by track, provided working ratios necessary to determine costs per graduate comparison, as seen in Table 1. As of this study, PTN only produced MAF and CAF tracks, whereas UPT has historically produced additional tracks (e.g., helicopter, remotely piloted aircraft). Since PTN has no comparable tracks to those additional UPT tracks, only UPT's values appear in the 'Other' column. Instead, since all PTN students share a common course length, this study focused on the ratio of graduates for cost development. This comparison helped frame PTN's single iteration against UPT's historical production, and provides track ratios—specifically the MAF to CAF ratio—for each training approach. For example, at 7% attrition the first iteration of PTN produced

thirteen graduates, seven MAF and six CAF for a ratio of 1.2 to 1 as compared to UPT's historical 2.4 to 1 ratio.

Table 1: Track Production Details by Training Approach

Program	Attrition	MAF		CAF		Other		MAF:CAF Ratio
UPT	8%	3,584	48%	1,460	20%	2,416	32%	2.4:1
PTN	7%	7	54%	6	46%	0	0%	1.2:1

Next the track ratios for UPT and PTN factored into each program's cost-per-graduate per year. This cost comparison included academic, both virtual and non-virtual reality simulators, flying and support costs for both training approaches. Using this approach helped avoid the disparity between budget-induced changes in logistics costs year-to-year and the variance of annual pilot production. Specific comparison costs are detailed in the Appendix.

The distinction between fixed and variable cost is important for this comparison as some costs are inherently incurred to run each program (fixed), while other costs change with variations in total student pilots (variable). For example, a program needs established base support and an operable airfield regardless of the number of pilots. These are considered fixed costs. Conversely, the number of simulators in each program is dependent on the total number of students in the program; additional students require increased hardware, driving the variable cost per student up.

For this study's comparison, shown in Table 2, a summation of academic, simulator, flying, and support costs for the T-6 and—for UPT only—the secondary training platform (CAF: T-38 or MAF: T-1) comprised both UPT and PTN's fixed cost per graduate. The variable track costs (sans support cost) incorporated a summation of each programs' academics, simulator, and flying costs. Ultimately, PTN's fixed costs

represent a fraction, 45% MAF and 28% CAF, of those for UPT. Following that trend, PTN’s variable costs are only 32%, MAF, and 13%, CAF, of those incurred by UPT. As an accounting validity check, this study’s CAF figures are 9% under, and MAF calculations are within 1% of AFI-65-503’s published figures.

Table 2: Cost Comparison Between UPT and PTN by Cost Type

<b>Cost Investigation</b>	<b>UPT</b>	<b>PTN</b>
Initial Cost: MAF Track, Per Student	\$ -	\$ 656,423
Initial Cost: CAF Track, Per Student	\$ -	\$ 648,888
Fixed Cost: MAF Track, Per Graduate	\$ 759,038	\$ 339,603
Fixed Cost: CAF Track, Per Graduate	\$ 1,138,144	\$ 332,068
Variable Cost: MAF Track, No Support Cost, Per Graduate	\$ 220,038	\$ 70,025
Variable Cost: CAF Track, No Support Cost, Per Graduate	\$ 432,296	\$ 62,491

### Production Analysis

The current UPT approach utilizes approximately 117 flight-hours in the T-6 training aircraft per graduate. After UPT, an additional 86 flight-hours for the T-38 CAF track or 78 flight-hours for the T-1 MAF track are required, depending on the pilot’s specialization. As noted previously, the largest benefit of PTN is the reduced number of aircraft and instructors required to train pilots. PTN’s innovative virtual reality training fulfills most of each pilot’s instruction and practice, requiring only 65 hours in the T-6 for training and real-world evaluation, regardless of track. For context, this means PTN effectively eliminates the need for UPT’s T-38 and T-1 flight-hours. Comparison of requirements between programs yields a ratio of flight hours (UPT T-6 to PTN T-6) equal to 117:65 or 9 to 5. This implies that if instructors and other support functions are available, PTN could increase pilot production by an additional 44.44% to match the current UPT T-6 utilization rate and flying hour program projections. Given the current 1,000 pilots produced per year, PTN production could increase to 1,444 pilots per year

with no additional operational costs (e.g. aircraft, fuel, maintenance) than currently allocated to UPT.

This analysis utilizes a concept coined ‘Pilot Ready Years’ as a unit of measure representing the aggregate time-service commitment produced annually for the Air Force. For example, the current UPT production is 1,000 pilots per year, each of whom incur a ten-year time service commitment upon completion of UPT. Each pilot may spend up to two of those time service commitment years waiting for an open FTU slot and then completing training. The USAF loses those Pilot Ready Years. Since the current annual production of 1,000 UPT graduates wait one year, on average, for FTU and require one year to complete FTU, then each graduate retains 8 years of commitment or 8,000 Pilot Ready Years ( $8 \times 1,000$ ) for the group, each year. This appears in Figure 3 as “Current Training.”

The next row, “Current PTN,” indicates the PTN approach with no other change in the production of pilots from before. While the timeline changes, the production and Pilot Ready Years remain the same. This means the same total number of pilots graduate, but the PTN graduates are mission-ready six months earlier compared to their UPT peers with no increase in total Pilot Ready Years.

The “Excess Capacity” row shows PTN replacing UPT and production raised to max capacity of 1,444 pilots per year, as discussed above. This condition still does not increase total Pilot Ready Years, and, more importantly, illustrates the problem of partial PTN implementation. Following Little’s Law, higher PTN production alone leads to a higher inter-arrival rate into the wait buffer between training, effectively increasing the queue length and total system wait time. This is due to the FTU’s inability to accept the excess capacity of new pilots given available aircraft, support personnel and

infrastructure constraints. In short, this becomes a pilot training bottleneck, contributing to delays in pilot production. If allowed to manifest, this could create a worse backlog, lower motivation, and increase organizational resistance to PTN's innovation.

To ease the bottleneck, it seems intuitive to simply replace UPT with PTN, synchronize training slots, and eliminate all wait-time. However, doing so has potentially negative consequences if not addressed carefully. Since PTN takes only six months, two courses fill the same timeframe as each year-long UPT course. If each PTN course tried to produce 1000 pilots every six months this would incur twice the utilization on training airframes and complicate scheduling. Additionally, this higher utilization rate on the T-6 could potentially drive time-intensive flying hour program and sustainment recalculations, and increasing resistance to PTN.

To circumvent this condition, the row labeled "Sub-Optimal," consists of adopting the PTN model for the entire pilot production process (UPT and FTU) to remove the bottleneck. This approach assumes production remains at 1,000 pilots per year (500 every six months) and elimination of all wait-time between training courses. The total training time reduces to 1 year versus 2.5 or 3 years, allowing for a 19% increase in total Pilot Ready Years, up to 9,500 per group.

This option sounds achievable, yet the USAF can do even better by setting annual production equal to the current annual T-6 flying hour allocation, as shown by the "Optimal" row. To ensure this change does not put T-6 utilization over allocation, total annual flying hours are divided between two six-month long PTN courses per year. This increases annual production capability from 1,000 pilots to 1,444 pilots per year (722 every six months). Now utilizing the PTN model for full pilot production (UPT and

FTU) and increasing pilot production consistent with the current flying-hour program yields 13,718 Pilot Ready Years ( $1,444 \times 9.5 = 13,718$ ).

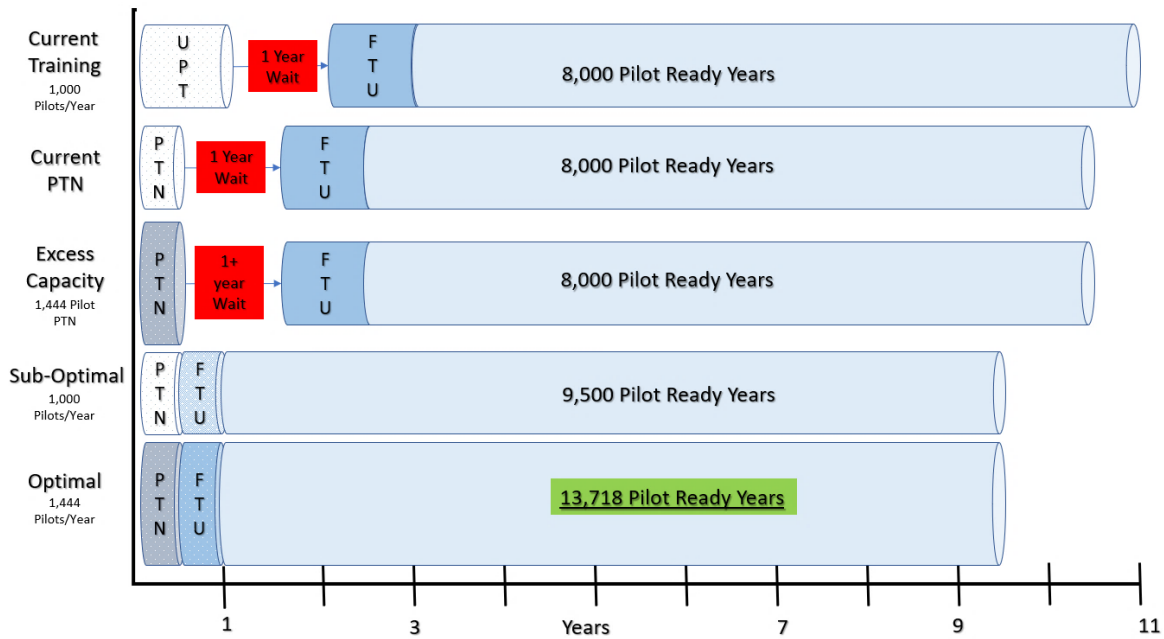


Figure 3: Pilot Production with Incremental Adoption of the PTN Approach

Applying the previous optimizations over a longer timeframe allows for a better understanding of consequence measured by the speed the USAF could theoretically recover from the current pilot shortage. Figure 4 results from using a ten-year timeframe broken up into 12-month segments for a comparison of cumulative pilot production values after implementing iterative improvements.

Stepping through the figure, the lowest output represents the current pilot training production: 1000 graduates per year progress through 12 months each of UPT, FTU, and the wait between UPT and FTU, yielding 8,000 pilots after 10 years. The next higher production represents PTN replacing UPT, with no change to the 12-month wait and 12-month FTU, yielding the same 8,000 graduates after 10 years. The difference between these two approaches is that the pilots will be ready six months sooner with the PTN implementation. If the wait-time is removed between UPT and FTU in the current pilot

production, this would yield the same 8,000 pilots one year sooner than the current approach, with a total production of 9,000 pilots after 10 years. Replacing only UPT with PTN and removing the 12-month wait prior to current 12-month FTU training also yields 9,000 pilots after 10 years. However, if the PTN approach replaces both UPT and FTU with all wait-time removed, total production reaches 9,500 pilots at 10 years, a 19% increase over current production. Finally, if PTN throughput is held at the current planned and budgeted allocation for the T-6 (1,444 pilots per year) to avoid sustainment consequences, total production yields 13,718 pilots after 10 years, representing a 71% improvement over current production.

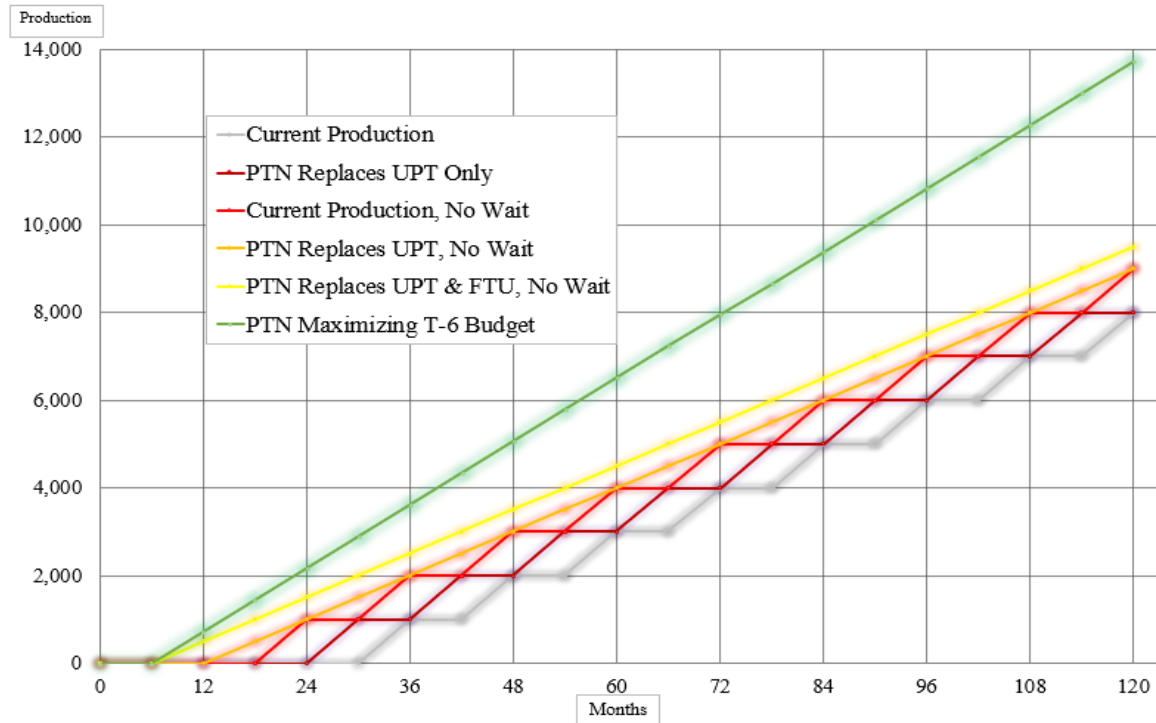


Figure 4: Comparison of Pilot Production Optimizations

## Quality

The quality portion of this cost-benefit analysis began with the understanding that quality could be compared by establishing quantitative metrics that were both accurate and useful [81]. Initially, this study sought the following metrics as acceptable measures

of quality comparison between UPT and PTN: track selection criteria and the average speed of pilots through each phase of training. These metrics should have added context and bolstered a comparison of evaluation flight scores. However, in developing these metrics, complications forced a shift in focus to the empirical evidence from instructor interviews as a more qualitative measure [82] for comparing UPT and PTN pilots.

One potential quality issue concerned class stratification. Competition and stratification are time-honored components of USAF training, and pilot training is no exception [83]. Both UPT and PTN train to minimum flying competencies, albeit through different scheduling timeframes because of aircraft and instructor availability and student progression. Additionally, each student's progression through the training phases directly feeds into a stratification that determines which track each student earns, and ultimately what aircraft they fly after graduation. With the increased utilization of virtual reality training, PTN's overall course length was significantly shorter when compared to UPT. This may have impacted instructors' ability to stratify students who were competing for specific tracks.

Looking closer at PTN student grades, it appeared PTN CAF graduates finished the first phase of training faster ( $69.17 \pm 6.68$  days) than PTN MAF graduates ( $87.86 \pm 10.76$  days). Due to course length restrictions this gave CAF graduates more time in the specialized training phase ( $47 \pm 5.37$  days) compared to their MAF counterparts ( $26.71 \pm 11.06$  days). This result implies that more highly motivated students may have more time in specialized training, thus gaining greater proficiency prior to graduation; this parallels the track differentiation and stratification methods of UPT.

With track selection synchronized, the next planned step for comparing PTN to UPT involves determining standardized evaluation flight scores for each phase of UPT to

benchmark against PTN evaluation flight scores. This comparison should employ a simplified non-parametric statistical comparison such as a Student’s T-Test, given the small PTN sample size. This information tells decision makers whether PTN scores fell within the historical average for UPT and shows how PTN graduates compared to their UPT contemporaries.

Unfortunately, supporting data for this portion of the cost-benefit analysis did not come to fruition. One reason for this appears in Figure 5. This thirty-month snapshot shows the grade variability of only one of four evaluation flights across three UPT bases. According to G-TIMS analysts, this grade variability is attributed to such disparate factors as each base’s different training syllabus, rotating instructor cadre, seasonal weather, and base-specific support limitations. Despite this information, this study is unable to tell which of those factors played a statistically significant role in that data variability. Additionally, various aircraft groundings and syllabus optimizations occurring concurrently with research efforts in 2018 further complicated data tracking and acquisition for this study [84], [85]. Attempting to draw conclusions and quality comparisons from such data would be both grossly inaccurate and irresponsible.

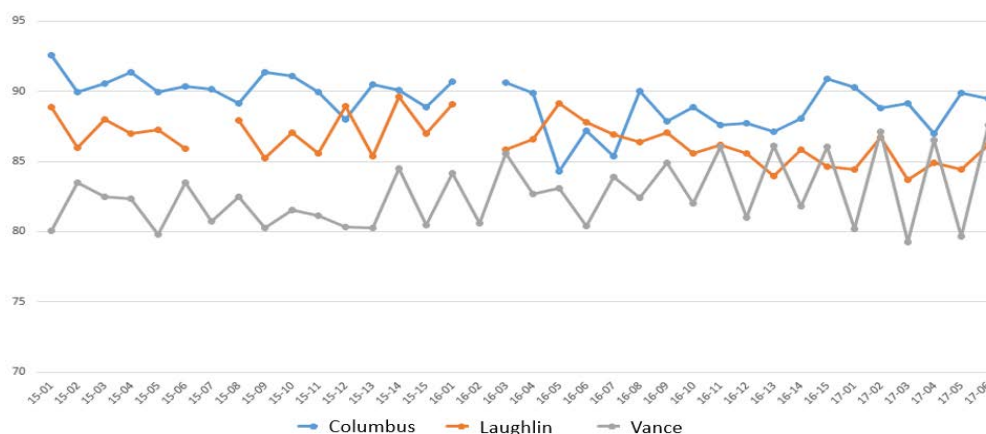


Figure 5: UPT’s T-6 Average Evaluation Score Variability by Training Location

Fortunately, a quality comparison between UPT and PTN was still possible through insight gained from instructor interviews. PTN's experienced cadre, with their significant insight from their combined experience with UPT, FTU, and PTN students, provided this study with unique positional feedback pertinent to the quality of the PTN approach.

During PTN, instructors act as both a coach and simulated air traffic controllers during student training and evaluation flights. This method adds both chaos and realism to the virtual reality training, augmenting each PTN student pilot's off-duty practice. Some instructors cited the experimental, low-threat atmosphere of PTN that gave each student more freedom to accelerate their own proficiency. Others claimed the adoption of more pilot-friendly technology and flexibility allowed instructors to teach each student in innovative ways. Still others cited benefits of selective recruitment and previous USAF training outcomes.

Despite the disparity in the underlying cause, PTN instructors were unanimous in the assertion that PTN graduates are talented, highly motivated, and promising aviators. Per the instructors, the greatest common impact to overall quality came from students' ability to strengthen their skills flying virtually prior to entering an actual training aircraft. According to PTN instructors, this practice enabled PTN students to fly 'leaps and bounds' ahead of their legacy UPT peers, even on their first flight in a real aircraft. This led to PTN students performing feats unheard of in legacy UPT, including performing landings without direct instructor intervention on their first flight in the training aircraft. According to instructors, this level of proficiency was not normally seen until the fifth UPT flight.

In a compounding cycle, class-leading students motivated instructors to engage opportunities to rapidly train on many different airframes without the limitation of needing to source real aircraft and learn the intricacies of specific operating procedures prior to flight. Halfway through PTN training, instructors claimed PTN pilots demonstrated superior T-6 proficiency compared to their UPT peers, and many showed comparable flight proficiency to mid-course FTU students. Furthermore, all instructors interviewed agreed that PTN graduates were at least as good as, if not better than many of the instructor's previous pupils taught using legacy USAF pilot training methods.

## V. Conclusion

This section redresses the research questions and their implication to the USAF, suggests ideas for future research, and provides the study's final thoughts. This study focused on comparing PTN to UPT with respect to *cost*, *production*, and *quality*, and the results of this cost-benefit analysis support PTN's innovation as the catalyst necessary for overcoming organizational resistance to virtual reality training in the USAF and, potentially, wider application throughout the DoD.

### Cost

This study's cost investigative question centered on the comparison of PTN's initial, fixed, and variable costs compared to UPT. While the initial cost was determined largely by budgeting and attrition, the more important comparison stems from the fixed and variable costs per graduate. As shown in the cost analysis, PTN's MAF fixed costs equate to less than half of UPT's, while PTN's CAF is nearly a quarter of UPT's CAF cost. Similarly, PTN's variable costs are a third and tenth (MAF and CAF, respectively) of UPTs costs. While the lower cost is attributable to reduced time-to-train and significant decrease in logistics costs associated with supporting multiple airframes (e.g., T-1 and T-38) the implications of cost savings extend beyond just pilot training.

The PTN innovation not only represents a significant cost savings for the USAF, but these savings will compound each year. Coupled with the maturation of more accurate financial programming, the USAF can simultaneously train pilots to offset the shortage and use the remaining funds to help procure new airframes for them to pilot in prosecution of the USAF's mission. For example, based on current PTN track ratios and full utilization of T-6 current flying hours, in ten years the USAF could train 14,444

pilots and fix the shortage at a savings of \$8.96B (fixed cost) and \$3.96B (variable cost). These funds could then be reallocated to other fiscally scrutinized programs like the B-21, T-X, KC-46, and F-35.

## **Production**

This study's two production investigative questions focused on determining PTN's impact to USAF mission-ready pilot availability with respect to aircraft and instructor utilization and determining how quickly full implementation of PTN—provided current support levels—could heal the current pilot shortage. While the analysis drew from the best available information during research, it must be understood that real-world application may not occur as cleanly and seamlessly as projected. Nevertheless, PTN, if applied to its full potential, offers a potential solution to the USAF pilot shortage.

Although PTN could produce pilots faster (approximately 6 months), simply replacing UPT with PTN does not represent the most optimal change. PTN graduates will still wait to enter and complete the FTU and additional training before they are mission-ready in their respective primary aircrafts. However, the PTN model provides great promise on many of the issues impacting current production and could have positive impact on pilot availability via 1) reduced hours required in each aircraft, 2) reduced demand for instructors, 3) increased total Pilot Ready Years. To wit, if PTN only replaces UPT this creates excess capacity and queuing prior to the FTU. If this flow is maintained throughout the training pipeline the PTN approach will not represent a net time-savings to the Air Force. At full application however, the Air Force could reduce

total wait time while significantly increasing production capability, with the added benefit of freeing up more aircraft for non-training purposes.

Keeping the current 2,400 pilot shortage in mind, one can safely assume this number represents the minimum number of pilots needed to rectify the shortage. Given the same conditions outlined in the analysis and assuming personnel levels hold constant, fixing the shortage using the current training approach would take approximately 60 months. Replacing only UPT with PTN eliminates the shortage in 54 months. Stepping back for a moment, not implementing PTN but removing the wait-time between UPT and FTU achieves the same outcome in 48 months. Combining the benefits of previous optimizations by implementing PTN for UPT and removing the wait-time heals the shortage in 42 months. Better yet, PTN replacing UPT and FTU training with a reduction of wait time could eradicate the shortage in as little as 36 months. However, if production is expanded to the current UPT's T-6 flying budget, or 1,444 pilots per year, the shortage would disappear in 30 months after full implementation. This solution represents a 71% increase in production without incurring the significant cost of over-utilizing the T-6 fleet. This approach also provides the USAF a single-source solution to the current shortage, while offering lower risk compared to the USAF's previously explored paths to fix the shortage.

## **Quality**

This study's quality investigative questions focused on establishing context and comparison of evaluation flight scores between PTN and UPT pilots. Additionally, when data acquisition to support this comparison failed to materialize, the study shifted to establishing a comparison of how PTN graduates perform versus UPT peers during initial

and follow-on training. Unfortunately, this effort failed to produce the intended quantitative data due to timing. However, the promising reports from PTN instructors, coupled with continued support of USAF leadership, adds to the motivation to continue studying, optimizing, and engineering virtual reality as a cost-effective method for increasing pilot production to offset the current shortage.

### **USAF Implications**

A strategic comparison of benefits indicates that PTN is better from a *cost* and *production* standpoint, but further analysis is required to make a comprehensive *quality* comparison. With increased fiscal scrutiny on government and military spending, PTN's cost savings alone should motivate the USAF to pursue the program. Similarly, PTN's ability to fix the current pilot shortage in as little as 30 months allows the USAF to get the desired end-state and frees Airmen to tackle other complex issues facing the USAF. Even the lack of concrete quality comparison should not dampen motivation. Continuous improvement during future iterations will provide quality comparison metrics, but the real benefit lies in the USAF's ability to utilize this time to decide the best mix of training capabilities and outcomes to produce the best pilots. Ultimately, each success in the PTN program increases validation, strengthens motivation, and positively offsets organizational resistance until PTN's innovation becomes the status quo for USAF pilot production.

### **Future Research**

As mentioned in the introduction, the lack of virtual reality pilot production optimization studies represents a wealth of opportunity for future research. If research interest includes USAF cost methods, AETC is, at the time of this writing, seeking a

better process for accounting and forecasting pilot production costs. On the production side, recent changes to UPT syllabi have reduced the time to train new pilots but USAF leadership still seeks optimizations and application for scheduling and synchronizing training between UPT and FTUs and integration of the new T-X system replacing the T-38 [23]. There is also room for study in the adaptation of the PTN approach to other airframes including drones, helicopters, and other specialized vehicles. For quality, there are even more options. Though time-intensive and complicated by many factors, securing historical UPT training data may yet prove useful. The data may permit development of interactions to establish key variables for a regression comparison [86] thus enabling an analysis of which training events are most impactful to forecasting pilot success. Additionally, this information enhances the mutually beneficial study of transfer of training effectiveness for flight training devices [67]. Ultimately, UPT performance may not be as meaningful to the future researcher as FTU and career performance. However, this presents an opportunity for a longitudinal study following PTN pilots over their careers, though choosing the proper comparison metric may prove challenging.

If research interests do not involve pilot training, virtual reality training presents opportunities to study adaptation to other fields, especially how to manage and succeed with such applications from the organizational development perspective. Examples for future study abound, including the following: studying the impact of crowd-sourced virtual reality training on long-term individual task proficiency; measuring the effectiveness of utilizing virtual training to improve recurring training and maintain task proficiency; calculating the opportunity cost and intrinsic rewards of returning former instructors to their primary roles; or delving into issues associated with international technology access restrictions, network and physical security concerns or associated

mitigation techniques. Virtual reality has great potential to impact learning and improve quality of life; now is the time to discover and define the USAF's path to that goal!

### **Final Thoughts**

By acquisitions and systems engineering standards, PTN exists in a prototype stage; the first step to achieving USAF shared vision for change. PTN—as an innovative first step to overcome the pilot shortage—produced positive results as a concept demonstrator. Next a low rate production phase should begin wherein changes and improvements can be made prior to full scale production [2], [87] to maintain motivation. This maturation, coupled with the knowledge gained in similar training improvement initiatives will set the USAF up with a dynamic and repeatable method for increasing pilot production. Successively improving production by fine-tuning the vital details (personnel, infrastructure, and training events) saves time, money, and frustration prior to going full-scale.

Following the axiom '*slow is smooth, smooth is fast,*' deliberately and methodically restructuring the training program will yield the pilot production the USAF needs: fiscally responsible, high quality training with lower risk than shutting down, retooling, restarting a new program, and with the benefit of no reductions in current production output. Using this approach may delay the pilot shortage solution but allow the current UPT to maintain production while PTN scales up. This approach allows the USAF to leverage technology improvements and industry best practices for a bespoke solution, dovetailing with current USAF leadership's vision and guidance.

Lastly, while PTN should not replace current pilot training immediately, the USAF should not wait to start a phased transition. Implementing virtual reality training

*now* will allow the USAF to capitalize on the strengths of the emergent technology to the cost advantage of the American taxpayer. As an early adopter, the USAF will benefit from the efforts of previous virtual reality training implementations but still enjoy priority when resolving initial issues, especially in light of fewer competing interests [88]. Ultimately, the experience will yield reduced learning curves as the USAF builds a continuously improving, cost-effective and leading-edge training solution to offset the current pilot shortage. PTN's virtual reality training, with best practices shared across the enterprise, not only solve the pilot shortage but also provide seminal success for the USAF and DoD.

## **VI. Appendix: Cost Calculation**

The following paragraphs detail the calculation method for the cost figures in Table 3 (below), as utilized for Table 2 (in Cost Analysis, above). Setting the benchmark, UPT platform specific costs (T-6, T-38 and T-1) were determined by multiplying the logistics cost per flying hour (from AFI 65-503 Table A4-1, for fiscal year 2018) by the average number of hours flown per student (from each respective syllabus). UPT's (non-virtual reality) simulator cost was based on that simulator's cost-per-hour multiplied by number of hours required per student (also derived from each respective syllabus). Support costs (base, payroll, and indirect costs) were calculated using AETC Training Cost per Graduate data and subtracting flying costs from total cost per graduate.

For comparison, PTN academic costs were derived as a ratio of PTN's 4-week timeline compared to UPT's six-week timeline multiplied against UPT's academic cost per graduate. Next, PTN flying hours were averaged from PTN student gradebooks, then multiplied by the logistics cost per flying hour (from AFI 65-503 Table A4-1, for fiscal year 2018). PTN track costs were then calculated from each track's average flying hours multiplied against the logistics costs. PTN support costs were held equal to UPT as both programs take approximately six months, implying they both should cost the host base approximately the same to support. PTN's virtual reality systems per-unit annual costs included virtual reality software licenses, maintenance, hardware, and setup cost, all sourced from AETC's financial management's contract wedge. Dividing these costs by the 20 initial PTN candidates provides the current fixed cost per student. To calculate the variable cost per additional student, the hardware cost was divided by four (representing the number of courses in two years) then added to the software licensing costs.

Table 3: UPT vs PTN Cost Comparison Components

<b>UPT vs PTN Cost Factors</b>	<b>UPT</b>	<b>PTN</b>
T-6 Academics (Weeks)	6	4
T-6 Academics Cost per Student	\$ 34,977	\$ 23,318
UPT T-6 Fly Hours	117	0
PTN CAF Track Average Fly Hours	0	54
PTN MAF Track Average Fly Hours	0	68
T-6 FCPH (logistics cost)	\$ 561	\$ 561
UPT T-6 Flight Cost = FCPH*Fly Hours	\$ 65,637	\$ -
PTN CAF T-6 Flight Cost = FCPH*Fly Hours	\$ -	\$ 30,423
PTN MAF T-6 Flight Cost = FCPH*Fly Hours	\$ -	\$ 37,957
T-6 Support (Base, Ofcr Pay, Indirect)	\$ 269,578	\$ 269,578
T-6 Simulator (OFT) Hours	52	0
T-6 Simulator (OFT) Cost per Hour/graduate	171	\$ -
T-6 Simulator (OFT) Total Cost	8,861	\$ -
T-6 VR Simulator Software License per unit	\$ -	\$ 5,500
T-6 VR Simulator Software Upgrades/Mx per unit/per year	\$ -	\$ 2,000
T-6 VR Simulator Equipment per unit	\$ -	\$ 20,000
T-6 Total Cost of VR Setup (Everything)	\$ -	\$ 6,336,401
Cost per student VR (total/20 students)	\$ -	\$ 316,820
Cost per additional student (VR) License, software, mx	\$ -	\$ 8,750
T-38 Flight Hours	86	0
T-38 FCPH	\$ 3,738	\$ -
Total T-38 Flight Cost = Fly Hours*CPFH	\$ 321,468	\$ -
T-38 Simulator (OFT) Hours	47	\$ -
T-38 Simulator (OFT) Cost per Hour/per graduate	29	\$ -
T-38 Simulator (OFT) Total Cost	1,353	\$ -
T-38 Support (Base, Ofcr Pay, Indirect)	436,271	\$ -
T-1 Flight Hours	78	0
T-1 FCPH	\$ 1,351	\$ -
Total T1 Flight Cost =Flight Hours*FCPH	\$ 105,378	\$ -
T-1 Simulator (OFT) Hours	61	\$ -
T-1 Simulator (OFT) Cost per Hour	84	\$ -
T-1 Simulator (OFT) Total Cost	5185	\$ -
T-1 Support (Base, Ofcr Pay, Indirect)	269423	\$ -

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<b>14. ABSTRACT</b> The United States Air Force (USAF) is currently facing a 2,400-pilot shortage in an increasingly constrained budgetary environment. Without pilots to engage the enemy, deliver weapons, and provide logistics support for operations, the USAF could lose the ability to fly, fight, and win global engagements and defend the homeland. This study focused on Undergraduate Pilot Training (UPT) as a means of producing the USAF's pilots to offset the current shortage. Specifically, this study compared UPT to the recently initiated Pilot Training-Next (PTN) program through a cost-benefit analysis. Like any new technology integration, PTN's virtual reality training will require further study for proofing and justification prior to full-scale implementation and further utilization of constrained USAF resources. This study's use of extant financial and historical production data, coupled with interviews with PTN instructors, highlights the potential of PTN. Ultimately, this study's cost-benefit analysis uniquely contributes to the growing body of virtual reality training research through a Formula for Change theoretical lens, while simultaneously providing USAF decision makers a comparison of program costs, projected production capacity, and quality of training.					
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