



The Mitchell Forum

Building Better Pilots: Considerations to Ensure T-X Success

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About the Forum

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Abstract

The T-X program must succeed, as it represents the foundation on which core US Air Force missions are based. Leadership is keenly aware that every year the T-38 Talon remains in service, sustainment costs will surge, while the aviators who will fly the Air Force's most modern and sophisticated, or "fifth generation," aircraft will not receive an optimum foundation of skills in pilot training. A simple aircraft replacement for the T-38 is not the goal.

A successful T-X acquisition must balance the competing demands of both procurement and operations and sustainment bow waves to best serve the long-term needs of the Air Force's most precious resource: Airmen. The fifth generation force structure will only be as good as the individuals who operate, maintain, and support its employment for generations to come. Consequently, both government and industry must pursue a T-X system that essentially transforms pilot training to meet the requirements of combat aviation in an era of the information-infused "combat cloud." At the same time, the enduring nature of the rapid-paced, high-demand training pipeline for novice aviators necessitates a high-use, durable, and supportable trainer aircraft within the T-X system.

In the time remaining, the Air Force can continue to work to get the T-X offering as right as possible by focusing on: meeting the highest performance demands for building fifth generation training; acquiring a total training enterprise, not simply an aircraft; further developing open mission systems requirements and beneficial live, virtual, and constructive standards; and pursuing value with a regard for savings across the program's life cycle.

Introduction

The US Air Force finds itself at a crossroads of competing budgetary challenges, as the long-debated competition looms large for the Advanced Pilot Training (APT) Family of Systems (FoS) program, commonly referred to as “T-X.” Although it sits in the number five spot of the Air Force’s top acquisition priorities, the program is vital to producing America’s combat Airmen effectively and affordably for generations to come. The Air Force faces a bow wave for procurement as well as one for operations and sustainment (O&S) that service officials must address as they craft an acquisition program to replace the venerable T-38 Talon, the service’s long-serving, primary supersonic jet trainer.

The APT FoS acquisition represents a major investment in continuing US airpower effectiveness, for American Airmen are dominant today because they fight as they train. Over the next 15 years, the Air Force will rapidly evolve into a more modern, “fifth generation,” and “combat cloud”-capable arm. The evolution of the associated training requirement will place new demands on an already stressed pilot-production pipeline, which runs from teaching basic flight skills as part of aviation training, to introducing higher end combat piloting competencies.

Increasingly, the T-38 training experience is becoming mismatched with the service’s “fight like we train” benchmark.

Today’s combat pilot is increasingly immersed in an information environment with unprecedented mission flexibility. Training is reaching a tipping point where the Air Force must apply expensive and inefficient work-arounds to compensate for T-38 obsolescence to achieve minimum proficiencies in fourth and fifth generation aircraft. A new training aircraft system is crucial to meet this challenge.

The T-38 replacement must be carefully designed to teach basic piloting skills, a “can’t miss” baseline requirement. At the same time, it

must also provide a path to a superior training environment that includes leveraging elements of live, virtual, and constructive (LVC) training suited for the front-end training pipeline. The family of systems must allow for a growing transference of fifth generation aircraft competencies across the training experience and into a pilot’s combat mission aircraft at a significantly lower cost than traditional training approaches. This integrated way to preparing pilots for fifth generation flight is critical for maintaining the Air Force’s edge.

However, the service will not acquire the APT FoS in a budget vacuum. It must remain focused on the fact that the T-X program must fit within a limited training budget. As important as T-X is, the program faces very real procurement and O&S budget constraints with the competing acquisition and O&S priorities for operational programs.

Given these constraints and competing priorities, the window to fix the Air Force’s combat pilot training situation is closing. Nonetheless, in the short time remaining in the preparation of the T-X request for proposal (RFP), there are areas that service officials can still fine-tune; this would allow the Air Force to achieve the most effective and affordable path to fifth generation pilot training without slipping the program into a zone where it becomes a bill payer for necessary fifth generation weapons systems. As imperative as it is to get the program moving forward, it is even more important to get it as right as possible in the time remaining. At stake is the ability to train Airmen efficiently and effectively to fully harness the dynamics of fifth generation air combat in the 21st century.

The Case For The Advanced Pilot Training Family of Systems

According to the Air Force’s most recent schedule, issued in August 2016, the service anticipates awarding the T-X contract in early Fiscal Year 2018, with low-rate production beginning in 2022 and the first T-X unit available for operations two years later.¹ Between 2022 and 2034, the service expects 346 T-X aircraft deliveries.² In this timeframe, it will simultaneously receive dozens of new fifth generation “sensor-shooter” aircraft, such as the F-35A Lightning II, the service’s

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newest multirole stealth fighter, and B-21 Raider, the future stealthy long-range strike platform. These new systems will place enormous demands on 21st century pilots. In addition to becoming skilled tacticians, future pilots will face tasks their predecessors could have scarcely imagined. These include operating and mastering a variety of weapons options, sensors, data links, and managing enormous volumes of intelligence, surveillance, and reconnaissance (ISR) information—all of which will be the lifeblood of a force integrated into a “combat cloud,” an eventual distributed network of communications, ISR, and strike systems which will be survivable and self healing in the face of a sophisticated adversary. Future pilots will simultaneously have to fly a superior aircraft and effectively manage information.

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The T-X aircraft will replace the T-38. The Talon fleet is approaching the half-century mark of service, and plans call for these airplanes to fly upwards of 70 years.³ The T-38’s history dates back to 1956, when the Northrop Corporation won a contract to develop an advanced supersonic trainer to teach fundamental piloting and airmanship skills to pilots who would fly the “century series” fighters (such as the F-100 Super Sabre, and F-105 Thunderchief) that began entering the force

in the late 1950s. These jets required intensive “stick and rudder” piloting skills—without any computer-aided assistance—as things happened very fast in these unforgiving aircraft. Making its first flight in April 1959, the T-38 has served in the Air Force’s training cadre ever since. It also entered service with NASA as an astronaut-training aircraft, and has flown in several militaries of allied nations around the world. However, by 1977, the Air Force was flagging the need for a replacement, and that requirement has bobbed its head for nearly 40 years.

Air Force officials claim it is long overdue to replace the T-38, and the service’s arguments are compelling. Military training aircraft rack up large numbers of high-stress flight hours. Young

and inexperienced pilots fly them hard. Over time, those stresses have added up on the Talons. Originally designed for just 7,000 hours of service life, the average T-38 has served more than twice this long, thanks to a series of costly life-extension upgrades, such as wing replacements and avionics improvements.⁴ Having personally flown as an instructor pilot in the T-38, I can attest that the training environment is astonishingly abusive on the airframe.

The typical T-38C, the newest Talon variant, has accumulated around 15,000 flying hours, and is forecast to amass up to 17,500 hours by 2017.⁵ This is a considerable amount of flight time for aircraft already facing age and maintenance challenges. According to the Air Force, the T-38 force has not met the requirement for 75 percent availability since 2011, and continues to experience mission-capable rates hovering around 60 percent or less.⁶ As these rates continue to fall every year, the cost associated with T-38 operations grows. Broken jets sitting on ramps lead to fewer students trained, with more dollars directed to sustainment versus flying training missions. The cost to fly these jets has also increased with time. In 2008, the cost to operate a T-38 for one operational flight hour stood at \$7,421. In 2010, that number rose to \$7,707, and by 2012, it jumped to \$9,233.⁷

The T-38 also falls short in meeting present and emerging training requirements. The Air Force’s combat pilot training pipeline breaks down into four main blocks: Initial Flight Training (IFT), where students begin learning basics of aviation; the multi-phase Undergraduate Pilot Training (UPT) segment, where students progressively learn skills required of all Air Force pilots and are eventually taught specialized skills for a particular aircraft; the Introduction to Fighter Fundamentals course (IFF) for instruction in base mission skills; and finally, the Formal Training Unit (FTU), where pilots learn advanced combat skills in a specific aircraft weapon system. The T-38 is now used in the advanced phase of UPT and in IFF. Tanker and airlift pilots, though, fly the T-1 in undergraduate training, a relatively modern Beech Jet 400 variant when compared with the T-38. After this phase, mobility students continue qualification in the specific airlift or air refueling aircraft they are assigned to. The T-X system, as envisioned, will

act as a bridge between the primary phase of UPT and the respective FTU for the sensor-shooter platforms.

As the Air Force brings on new aircraft, such as the F-35 and B-21, it is transitioning into a more-focused “fifth generation” entity that will require its pilots to master information age warfare as much as the fundamentals of flight. Learning sensor operations in these aircraft is now just as important as flying the jet. The T-38 is increasingly a training anachronism: a supersonic jet fighter, built to hone stick-and-rudder flight skills, but lacking relevance needed to produce superior pilots for the modern Air Force—from the F-22 Raptor and F-35, to the

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upcoming B-21. All of these are flying sensor-shooters that will act as critical elements in forming the information-age combat cloud.

The Air Force has pursued a replacement program for decades now, knowing it faces both sustainment challenges with the T-38 and training demands for the 21st century force. This modern training approach goes beyond buying a new aircraft. It must also incorporate training tools, such as high-fidelity simulators, digital learning devices, and other technological advances to flight training. These are essential assets to educate Airmen in how to command their jet, weapons, and information in a networked, enterprise fashion. In addition to gaining a higher quality training experience, these tools drive efficiencies by teaching and reinforcing procedures, habit patterns, and skills on the ground rather than in the air.

The T-38’s increasing obsolescence is driving costly work-arounds to maintain the present training pipeline. Back in 2010, then-Air Education and Training Command (AETC) boss Gen Stephen R. Lorenz said the Air Force was rapidly approaching the time where it would have to make a decision on a new trainer.⁸ This, he said, was due to the challenges of adapting pilot production to prepare a force of fifth generation Airmen and the

impact on how training flying hours are allocated between training assets and other FTU assets. A new F-22 pilot, he noted in September 2010, will train on the T-38, but then must fly several sorties in the F-16 Fighting Falcon before advancing to fly the F-22. This effectively represented a double bill to the service, spending limited dollars on multiple training assets instead of in an efficient and streamlined training enterprise.

As the Air Force’s fifth generation force structure has grown, and resources continue to remain tight, the problem has worsened. “I can’t produce enough F-16 pilots today,” said Lorenz’s successor, then-AETC Commander Gen Edward A. Rice Jr., in February 2013.⁹ “I can’t afford to get into a situation where I have to use F-16s in large numbers to train in for F-35s. ... That’s part of the calculus with T-X,” he said.

Compounding this challenge, the Air Force faces a severe pilot-production problem. The service is short more than 700 pilots across the force in 2016, and is expected to be 1,000 short in several years, said Air Force Secretary Deborah Lee James during a briefing at the Pentagon in August 2016.¹⁰ Though AETC’s Active Duty training pipeline will increase pilot production from 200 in 2016 to 285 in 2017, it is difficult to rapidly address the shortfall since it takes two full years to produce a new combat pilot.¹¹ On top of this problem, the new normal for an extended period will entail an estimated loss of 2,000 pilots a year to commercial airlines as industry trends and global economic conditions allow the sector to expand, while baby boomer pilots age-out and retire.¹² The Air Force’s shortage will burgeon, making a dependable, supportable, high-utilization platform all the more relevant to the service’s capability and readiness.

Bottom-line: the Air Force cannot afford ineffective and duplicative training approaches in an era where resources are tight. The B-21, F-35, and KC-46A Pegasus—the service’s top three acquisition priorities—will ramp up production as the 2020s arrive, putting more pressure on the service’s procurement and O&S accounts at the same time it needs a new trainer.

Service leaders know they have a narrow window to effectively field a new training aircraft system in force, a challenge that grows more acute with every passing year. Either the Air

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Force succeeds in hitting the acquisition window of opportunity, or it will incur severe training, personnel, and O&S consequences. Recognizing the stakes, then-Air Force Undersecretary Eric Fanning commented in March 2014 that the T-X effort was an “existential investment for the Air Force.”¹³

Understanding The Advanced Pilot Training Family of Systems Requirements

In October 2009, the Air Force created an initial capabilities document (ICD) defining the gaps in advanced pilot training that it needed to address by 2018. The document identified 12 shortfalls, which the T-38C fleet is presently incapable of performing, out of 18 mission tasks.¹⁴ The gaps include the T-38’s lack of: high-angle-of-attack design and higher thrust-to-weight ratios; software-driven emergency diagnostic tools; fly-by-wire flight controls (i.e., computer-regulated and assisted flight controls); updated Federal Aviation Administration-compliant system design requirements; and ability to perform night training, all-weather formation training, and beyond-visual-range formation training.

The Talon, simply put, is aging out of current mission demands. The ICD informed the maturation of requirements over time, and

AETC issued the first complete T-X draft request for proposal in July 2016. The RFP has since undergone several iterations and updates as Air Force officials refined the requirements, including abandoning an initial non-developmental item (NDI) approach for one that allowed and encouraged new “clean sheet” designs. The RFP’s final issuance is expected in late December 2016. Despite upgrades to the T-38 fleet over time, Air Force officials believe the T-38 is incapable of meeting the advanced needs of a force that will overwhelmingly comprise fifth generation assets. Indeed, more than 50 percent of the force will consist of B-21s, F-22s, and F-35s by 2031, if current plans hold.¹⁵

By 2034, the Air Force is expected to field the roughly 350 T-X aircraft it wants; it will not

be able to fully divest T-38s until then.¹⁶ Thus, it is paramount to field all the T-X aircraft, not just the initial deliveries, on time and on schedule. With all research, development, testing, and evaluation activities tallied, the procurement expenditures for the effort could cap out around \$16.3 billion over the course of the T-X contract.¹⁷ However, using studies from the Office of the Secretary of Defense’s Cost Assessment and Program Evaluation (CAPE) shop as a guide, the estimated cost of operating and sustaining the T-X fleet will likely dwarf that procurement bill by amounting to around \$28 billion over the life of the program.¹⁸

AETC, in its T-X concept of operations, lays out its demands for the new aircraft and associated family of systems. These include being able to conduct high-G force training, which places enormous gravity-multiplying stresses on a pilot’s body representative of modern fighter aircraft operations; advanced cockpit resource management tasks, such as data and ISR fusion; high-angle-of-attack flight; and “transferable” air-to-air and air-to-ground skills. The T-X system must also better prepare pilots to use data links, such as Link 16, as well as teach them the use of modern sensors via simulation tools.¹⁹

The Talon’s lack of fifth generation instruction capability is an enormous factor driving the acquisition of T-X. According to the ICD, AETC’s T-X concept of operations, and additional Air Force documents, the T-38’s performance and sensor-instruction limitations, among other gaps, present significant difficulties for future flight-training operations. Sensor- and data-management skills are, in particular, essential knowledge areas to teach fifth generation Airmen.²⁰ This dynamic creates a challenge in both sustainment and training across the force. Because of the T-38’s shortfalls, formal training units must now complete two-thirds of all Talon mission tasks. Pilots of combat aircraft, such as F-16s and F-22s, must complete training at a higher cost since these platforms are more expensive to operate than a dedicated training aircraft. These airplanes are also in demand as combat assets. For example, as noted above, AETC briefly tried to use two-seat F-16Ds with students in the F-22 pipeline for tasks such as high-G training with an instructor pilot in the rear cockpit. The course was considered inefficient and

ended in 2014.²¹ The Air Force wants to carry out such activity in the T-X in the future.

As the final version of the RFP nears, Air Force leaders and program officials have made no secret on how they view the T-X requirements and criteria: they want a modern training system, not just an aircraft, and affordability is paramount. A holistic system is necessary. “Affordability is one of the prime factors we are looking for,” said AETC Commander Lt Gen Darryl L. Roberson in September 2016.²² Price will have “a much bigger impact” than the difference between the bare-minimum system requirements and “nice-to-have” performance capabilities of a given offer, he said. This is a tricky balance to keep when reconciling the need to procure a modern training

system, while also keeping requirements from growing excessively. Reflecting the desire to build a system that accommodates the needs of modern training, Roberson said the closer the service can get to “replicating that fifth generation environment, the more comfortable we are going to feel turning somebody loose for the first time on an airplane like that.”

To support this, a draft version of T-X request for proposal issued in July 2016 included incentives for companies to address key performance aspects of capabilities like ground collision avoidance; a ground support station that allows instructors to change in-flight scenarios; an embedded targeting pod; and sustained G capability of 7.5. In total, \$338 million in incentives are on the table to contractors who can meet these specific tasks.²³ However, when looking at the size of the T-X contract, this is a small percentage of the estimated \$16.3 billion fielding effort and \$28 billion sustainment activity, and Roberson conceded that the incentives are not large enough to sway the program on their own, in all likelihood.²⁴ Industry officials, meanwhile, are seeking more clarity on a few aspects of the RFP as the deadline nears; several have noted the Air Force has worked hard to create a two-way dialogue to answer questions and keep the program

transparent. It is important for the Air Force and other stakeholders to maintain this dialogue, as the Air Force and other US military branches are increasingly calling on companies to address capability gaps using their own internal research and development funds.²⁵ This approach will only succeed if the aerospace industry has confidence it understands the government’s requirements.

Whichever industry team emerges as the winner of the forthcoming competition, the Air Force must keep its eye on several factors to ensure the program’s goals are realized. Those goals are to produce combat pilots more efficiently and effectively for the future force and to optimize the quality of training for Airmen who will fly and fight in the information age.

In the remaining time before the service issues the T-X RFP, the Air Force should continue to fine-tune its offering in the following key areas to obtain the best solution for the Advanced Pilot Training Family of Systems:

1. Meet the highest performance demands for building fifth generation training.
2. Acquire a total training enterprise, not simply an aircraft.
3. Further develop open mission system (OMS) requirements and live, virtual, and constructive (LVC) standards.
4. Pursue value with a regard for savings across the program’s life cycle.

Key Focus Area:

Meet The Highest Performance Demands For Building Fifth Generation Training.

The main theme across the Air Force’s T-X mission documents, request for proposals, and statements of senior leaders, is the overriding imperative to transition to a system that better prepares future pilots to operate in a world where networks, data links, and mission system operation skills are just as important as learning how to perform basic flight maneuvers.

The 12 of 18 capability gaps referenced earlier between the T-38 and T-X are replete with examples of how the present jet fighter training force is ill-equipped to train modern information-age combat pilots. The T-38, for example, cannot provide the cockpit resource management (CRM) skills training to the degree necessary for fifth

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generation pilots. The Talon's lack of sensors and inadequate data-fusion tools are not reflective of the "high-complexity cockpit-management skills" that fifth generation pilots will have to hone, such as managing modern situational awareness systems, secure data-link operations, and advanced fifth generation air-to-air and air-to-ground tasks.²⁶ Nor are the T-38's flight characteristics reflective of modern combat aircraft. Talons are not capable of performing either basic or advanced air-to-air combat skills training, as they lack sustained high-G capability and fly-by-wire technology. Students must spend time learning how to fly the T-38, then re-learn skills for their primary combat aircraft, a drain on Air Force training dollars and pilot production.

This problem expands as the Air Force sees its fifth generation force structure grow and faces an escalating pilot shortfall. The service is seeking to channel many of the training tasks that have migrated away from T-38s back into the T-X.²⁷ To understand how this affects the future of Air Force pilot training, it is necessary to return in more detail to the three main blocks of the combat pilot training pipeline: the multi-part Undergraduate Pilot Training, the Introduction to Fighter Fundamentals, and the Formal Training Unit. Each block has numerous courses, with specific objectives, and increasing cost as a pilot progresses.

Following graduation from Initial Flight Training, a student pilot arrives at the beginning of UPT, officially known as Specialized Undergraduate Pilot Training (SUPT). The primary phase of this step has a student pilot flying a T-6 Texan II, before graduating to the advanced phase, which occurs in a T-38. SUPT's primary phase teaches basic skills required of all pilots. The student progresses to the advanced phase where focus is placed on basic mission-specific skills associated with fighter or bomber aircraft. These skills establish a foundation for follow-on courses for the pilot's assigned mission aircraft: fourth and fifth generation fighters and bombers. Graduates of SUPT are awarded an

official aeronautical rating as a pilot, and those selected to fly fighters, for example, continue to the next step in the progression, IFF. There is a slightly different path for student tanker/airlift track pilots who graduate to the advanced phase of SUPT. These mobility student pilots fly the T-1 in this phase, a relatively modern Beech Jet 400 variant. After completing their training in the T-1, mobility students continue qualification activities in the specific airlift or air refueling aircraft they are assigned to.

IFF training focuses on building a base of operational knowledge for the fighter mission and tactical skill in a less-expensive aircraft than the one the student will eventually fly. This phase is currently conducted in the T-38. IFF modifies training more specifically to meet the demands placed on pilots of specific aircraft. For example, pilots who will fly primarily air-to-air-oriented fighters (e.g., F-15C Eagles, F-22s) will have a nearly exclusively air-to-air-focused syllabus. Pilots of multirole aircraft or air-to-ground platforms (e.g., A-10 Thunderbolt IIs, F-16s) will have varying amounts of air-to-ground tasks and training events in their syllabus, along with basic air-to-air training.

Pilots who graduate IFF move on to their specialized operational aircraft and further training takes place in the FTU, the training unit that specifically operates the actual combat aircraft variant. This is the last phase of the training pipeline, and upon leaving the FTU, a pilot is assigned to a combat unit. The goal is to get individuals as prepared as possible to qualify as combat-mission-ready (CMR) pilots, as determined by the combat unit. At the same time, the cost per flying hour of a typical combat aircraft is significantly higher than a T-38. For comparison, in 2012, the operational cost per flying hour of a T-38C stood at \$9,233. The cost to operate an F-16 for an hour was \$22,315; an F-15E Strike Eagle came in at \$35,365, and an F-22 was \$60,503 per flying hour.²⁸ As the Air Force seeks to add more fifth generation assets to its force structure, the cost pressures on the FTU will only rise if the service does not address the T-38's training gaps in an efficient manner. This means it must push as much training back into the T-X enterprise as possible.

It is important to recognize the difference between sustaining training aircraft versus

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**Key Focus Area:
Acquire a Total Training Enterprise,
Not Simply an Aircraft.**

Setting the T-X apart from the purely stick-and-rudder training derived from the T-38's initial concept of operations is the fact that it will integrate technology, simulation, and LVC training unlike any previous program. The need for more qualitative training in modern, high-threat scenarios is just as important on the ground as it is in a high-performance jet aircraft. "[We] are focused on getting the state of the air capability in the virtual constructive environment so we can, from the beginning, train to a level that's going to allow us to fight in that [high-threat] environment," said AETC's Roberson in September 2015.³² The T-X and its accompanying aids and simulators will need to train a pilot in a manner that the pilot will have a hard time telling whether he or she is actually flying an aircraft, he said.³³ This will be vital to ensuring that skills honed in the early stages of the training pipeline, before arrival at the FTU, will translate more effectively and efficiently to modern aircraft.

In short, the better the simulation technology used in conjunction with the T-X aircraft, the more tasks pilots will be able to perform more effectively and inexpensively both on the ground and in the air. A pilot does not have to learn the basics of operating a radar or data link in the air or with a real radar, for that matter. A high-fidelity simulator could also replicate actual handling characteristics and enable better simulator training for tasks, such as approaching a tanker for refueling. Every time a student straps into an actual jet, he or she will have appropriate skills "transference"—the Air Force's terminology for learning that directly applies to follow-on aircraft in a training pipeline—to perform more effectively. This means while the T-X often is looked at as an aircraft program, it will be, in fact, a system of systems, as per its official title: Advanced Pilot Training Family of Systems.

AETC's concept of operations refers to the T-X as "all systems—live, virtual, and constructive ... working together to enable APT."³⁴ They consist of the eventual T-X aircraft; a ground-based training system (GBTS) that encompasses simulators and training devices; computer-based training aids; and classroom academics. LVC is rapidly emerging as a

FTU and combat-coded aircraft. On a combat platform, sustainment activities are more diverse and demanding than on training aircraft. This includes maintaining weapons systems, along with mission avionics, threat-detection packages, and other systems not present in training airplanes. Combat aircraft also have significant "back shop" maintenance needs, such as caring for weapons and their software integration and hardware like carriage pylons. On fifth generation aircraft, further

expenses include stealth coatings, advanced radar, and sensor maintenance.²⁹ For these reasons, the T-X family of systems must adopt a LVC approach to training, in lieu of adding actual radars, targeting pods, and other sensors to the trainer aircraft, due to both procurement and O&S budget constraints. Air Combat Command (ACC) is addressing its graduate and continuation training shortfalls through LVC, and the Air Force must avoid a costly "stove-piped" solution—meaning not well coordinated—for the T-X by

ensuring the T-X FoS LVC is compatible with ACC's LVC standards.

The T-X aircraft and system, if fielded according to plan, will replace the T-38's role in the advanced phases of SUPT and in IFF. The T-X and its accompanying systems and training aids would effectively perform the 18 tasks required in these phases of the training pipeline, thereby closing the gaps in the Talon's current capabilities and allowing the transfer of tasks now performed by aircraft in the FTU phase of the pipeline back into the T-X family of systems. By doing this, the T-X system will "reduce ownership, operation, and support costs—while increasing readiness and operational capability" compared to the T-38 fleet, states AETC's Advanced Pilot Training concept of operations document, released in May 2016.³⁰ It will also will enable frontline combat training units to improve qualitatively the flying hours they are allotted to advanced combat skills training, instead of filling in training gaps for pilots.³¹

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standard within Air Combat Command and will be the cornerstone of affordable fourth and fifth generation training capabilities. The Air Force should ensure it examines existing ACC lessons and standards for LVC that are clearly suitable for the APT FoS and relevant to the SUPT/IFF training mission.

In concert with the concept of operations, the LVC system approach should ensure that the APT system provides a continuous learning environment for aircrew and maintainers, including briefing, debriefing, mission planning, and mission/maintenance task rehearsal. Similar to other programs of record, T-X should incorporate self-assessment tools to provide feedback to the user and to the training-management system.

As simulator technology has improved and as modern fighter aircraft continue to evolve into complex machines—where sensor and mission management are skill sets on par with physically operating the aircraft—ground-based training systems can supplant

in-cockpit flight time for an increasing share of training. AETC's capabilities document outlining the T-X system states that high-fidelity simulators that can replicate advanced radars and sensors, and aircraft performance characteristics will enable "more accurate simulated flying training, and will allow for more offloaded training opportunities."³⁵

These elements are not "gold-plating" extras—meaning items that are nice to have, but not essential—but rather will be critical to delivering efficiencies. From fuel costs to operations and maintenance, this approach promises real savings over time. If the T-X system is fielded on time, as planned, there could be a 35 percent increase in simulator utilization by "offloading," or moving, live-fly training into these more capable simulators during the IFF training phase, according to Air Force capabilities documents.³⁶

The inclusion of all this LVC technology will add upfront cost to the program. However, long-term savings will result from conserving

valuable and expensive flying hours at the FTU level of training. Plus, these simulation systems are far better attuned to teach fifth generation information-management skills early on in the training pipeline, skills that the T-38 curriculum does not capture.

The T-X's simulators break down into three main blocks of training technology: Unit-Level Training Devices (UTD), which are rudimentary simulators for basic tasks; the Operational Flight Trainer (OFT) that provides more advanced flight profiles, including more-complex IFF-level tasks, such as visual patterns and landings; and the Weapons System Trainer (WST), the high-fidelity simulator with networked capability that can provide operational flight training as well as basic fighter maneuver training.³⁷ Air Force leaders have often referred to "high-fidelity simulators," which can effectively duplicate the skills of live-fly training and save valuable flying-hour expenses, and have expressed how they want to expand their use in combat training. The WST will be the equivalent of this type of simulator, as it will have the highest resolution capabilities and the greatest field of view for the pilot. It can most readily teach students tasks, such as formation flying and tactical maneuvering with the greatest skill transference to actual flight operations.³⁸

Taken together, the Air Force is clearly betting that whichever industry team wins the T-X competition, it will be able to field the system on schedule and enable not only more qualitative training of modern combat pilots, but the recouping of valuable flying-hour costs now spent at the FTU level. This approach seeks to avoid spending resources retraining students whose skills do not translate from the T-38 curriculum to present requirements.

The Air Force needs to remain focused on attaining this enterprise approach, for budget decisions have historically pinched pennies by cutting procurement and sustainment of simulation and assorted non-aircraft training components. The service must stop this habit, as it is now a dangerous relic of 1950s-era attitudes. Pilot training for fifth generation combat aircraft demands an enterprise approach and the technologies available today are unlike anything seen in decades past. Splintering off pieces of

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this design concept will unwisely retain most of the capability gaps the Air Force is trying to close with T-X. Costly work-arounds and suboptimal training practices will increasingly dull the service's airpower edge.

Key Focus Area: Further Develop Open Mission Systems Requirements and Live, Virtual, and Constructive Standards.

The effort to replace the T-38 enterprise must seek to keep upgrade and growth opportunities open for future mission evolution and potential international sales. Without unnecessary "gold plating" of essential training needs, it is important to recognize that the T-X may have far-reaching value beyond the training mission. The Talon's own design and history reveal a similar story.

The T-38's longevity is in no small part due to its relative adaptability to several missions and tasks through the years. Although the Air Force initially fielded the T-38 as a training aircraft, it has gone on to perform in multiple missions in the US inventory...

The T-38's longevity is in no small part due to its relative adaptability to several missions and tasks through the years. Although the Air Force initially fielded the T-38 as a training aircraft, it has gone on to perform in multiple missions in the US inventory, such as testing experimental equipment, serving as companion trainers to help combat pilots maintain proficiency, and, more recently, flying as mock adversaries in training drills with F-22s. The Talon has also served in the militaries of allies around the world. A total of 1,187 T-38s

rolled off Northrop's production line between 1959 and 1972.³⁹ In order to extend its life, the T-38 received multiple upgrade programs over its service, including avionics replacement, engine modification, and wing replacement. This platform also served as the basis for Northrop's F-5 Tiger, a light fighter that went on to serve in the air forces of numerous US allies during the Cold War.⁴⁰ The Air Force should build the T-X to afford similarly broad employment and adaptability going forward.

The fact that the Air Force is updating its acquisition process at the same time that the T-X program is ramping up will aid T-X in this regard, as Air Force Secretary James articulated in early 2016. The service wants to "engage the defense industry earlier during the [acquisition]

process by which new requirements for weapon systems are developed and formalized," she wrote in January 2016 in a commentary explaining the policy shift towards a new acquisition approach called the "Bending the Cost Curve" initiative.⁴¹ Four programs have formed the pilot effort of this approach: the Long Range Standoff Weapon, the notional replacement for the AGM-86 Air Launched Cruise Missile; a data link system to join fourth and fifth generation aircraft; the Space Based Infrared System (SBIRS); and T-X. Each of these programs received cost-capability analysis to detail tradeoffs, stated James, adding that Air Force officials are sensitive regarding the importance of this aspect of acquisition. However, it is "too soon to know what type of savings" these programs will achieve, she noted.⁴² James also emphasized the inclusion of open mission systems architectures in key programs, such as the B-21. Such architectures will enable the Air Force to change out parts of the aircraft's mission systems as threats, technology, or even business cases evolve over time without getting bogged down in costly and onerous proprietary control issues. Service officials have moved to create a permanent open systems acquisition process and have identified additional programs they want to participate in this effort, she wrote.⁴³

As far as the Air Force's T-X requirements go, the RFP language currently falls short of the service's full OMS standard requirement. Instead, the language states that the program requires an "open system, service-oriented architecture that utilizes a modular design" in which functionality is broken into "discrete, cohesive, and self-contained units" with documented, publicly available, and non-proprietary interfaces and standards.⁴⁴ This is to accommodate future system upgrades and modifications as feasibly as possible. The approach should apply to all "key components and interfaces" for hardware, operational flight profile software, and systems integration software.⁴⁵ In short, the Air Force is requiring the inclusion of open systems architecture, but not directing how. A company can use OMS standards or proprietary standards to accomplish the goal of building an open systems architecture, but it would have to provide data rights to the US government.⁴⁶ To avoid a T-X stove pipe and to clarify government intent to reduce costs associated with future sustainment and

upgrades, the Air Force should explore application of OMS and LVC standards, as suitable, for the T-X FoS. This includes making the program adaptable enough to pass foreign arms-export regulations to allow US allies to potentially field the T-X system. The United States still utilizes the T-38 in numerous roles, and allies operate it as a trainer.⁴⁷ The cost of adapting the T-X for other missions or foreign sales should not be unreasonable, and indeed could prove a long-term success similar to the T-38's accomplishments in this regard. By allowing for both mission and export adaptability, the US government would afford a clear path for industry to recoup investment in developing the T-X aircraft to meet the Air Force's needs, while also further amortizing the service's long-term sustainment bill.

Key Focus Area:
Pursue Value With a Regard For Savings Across The Program's Life Cycle.

An efficient training jet needs to be reasonable to operate to maximize time in the air executing its mission, not stuck on the ground costing money and slowing pilot production. Growing sustainment and operations costs are a big reason why the Air

Force is pushing to get T-X on the flight line soon. As detailed earlier, the T-38 is problematic in this area. Sustainment is a significant reason why the service is looking to acquire a low-cost asset that does not pose similar challenges in the long term and will remain viable for several decades.

T-X provides an opportunity to net efficiency savings two ways: through the broader training enterprise and through reductions in the cost per flying hour of the actual jet. As discussed throughout the paper, enterprise savings are derived from ensuring training occurs in a streamlined, cost-effective fashion. The Air Force should use appropriate elements of LVC training to develop a range of skills, given that electricity is far less costly than jet fuel and systems. These include teaching students how to operate on-board and off-board systems during aircraft intercept flights, how to execute two-ship maneuvering and tactics to engage enemy aircraft, and how to utilize night-

vision goggles. Enterprise savings also involve better management of the training fleet. The Air Force will benefit from "downloading," or shifting, costs now borne by combat jets at FTUs back to the T-X at the UPT and IFF phases. By executing training in a more logical fashion according to mission requirements and not the limitations of the T-38, the Air Force also saves money by streamlining efforts, reducing duplicative course work, and circling back to address "negative training"—meaning correcting obsolete methods of operation associated with the T-38 that are no longer relevant for the present force.

From a direct aircraft approach, the T-X program affords the potential to yield a platform that will maximize key aspects of life-cycle cost. This includes fuel burn, maintenance expense, and an enduring service life. As the Air Force articulates, the T-X program is designed to ensure that the aircraft "minimizes total life-cycle cost while achieving readiness and sustainability objectives."⁴⁸

One of the program's key requirements is to reduce thrust-specific fuel consumption by 10 percent compared to the T-38's J85 engine.⁴⁹ While this technical efficiency requirement loosely aligns with targets set in the Air Force's Energy Strategic Plan of March 6, 2013, it does not actually address how much fuel an aircraft consumes for a particular mission and, therefore, misses the objective. If industry offers solutions that can reduce fuel burn compared to the T-38, the Air Force should encourage such fuel economy, since the T-X's mission is to fly as much as possible. Fuel burn is a significant factor driving life-cycle costs.

Another important factor in this life-cycle vein is building a jet that will be efficient from an operations and sustainment vantage. These expenses are related to factors like personnel, support equipment, software, logistics, and maintenance. While buying an aircraft is always expensive, these factors drive a platform's cost over its lifespan. Fielding an aircraft that can be operated in a regular, reliable, and efficient fashion will prove quite important.

Finally, the T-X is likely to remain in the Air Force's inventory for decades. As a unit of measure, the T-38 is currently slated to stay in the inventory past the type's 70th birthday. While the T-X's current RFP stipulates a design life of 22 years, it is

T-X provides an opportunity to net efficiency savings two ways: through the broader training enterprise and through reductions in the cost per flying hour of the actual jet.

likely that the new trainer aircraft will have tenure far exceeding that time.⁵⁰ This demands a system that is strong enough to sustain decades' worth of hard use, is upgradable with ease, and is adaptable.

Program goals have already shifted, in part due to the Air Force's evolving acquisition approach. The service first released the T-X schedule in late 2015, which included engineering, manufacturing, development, production, operations, and sustainment target dates. The Air Force has updated the schedule on five different occasions, in part related to its "bending the cost curve" policy.

Secretary James' effort to "bend the cost curve" should not apply just to the initial acquisition phase of the aircraft, but also consider some evaluative weighting of savings throughout the T-X's lifespan.

While time is running short to revise the acquisition strategy, long-term O&S cost advantages may result by factoring life-cycle benefits into the evaluation, to the extent possible. With a service life expected to exceed well over 40 years, the decision the Air Force makes with T-X will not only shape pilot training and combat

capability downstream, but will be subject to the modernization challenges of Air Force budgets for decades to come.

Industry Perspective And Implications For T-X Acquisition Managers

At this time, the assessment of the "can't miss" T-X program is well short of perfect. Reviewing requirements, a T-X capabilities document first appeared in 2009. A draft of systems specifications for the T-X aircraft and the ground-based training system came out in July 2015, and after several draft iterations of requirements, the Air Force released the final aircraft specifications to industry in July 2016. However, the service had yet to issue the final specifications for the ground-based element, as of early December 2016.⁵¹ In other words, despite years of work, a final definitive layout of the requirements and specifications is still not at hand, although it is expected before year's end.

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2015, which included engineering, manufacturing, development, production, operations, and sustainment target dates. The Air Force has updated the schedule on five different occasions, in part related to its "bending the cost curve" policy. The service has also pushed the T-X program's full operational capability (FOC) milestone to Fiscal Year 2034 from Fiscal Year 2032.⁵² The final RFP was slated for release no later than September 2016, but then slipped to December 2016. The contract award date has also moved from Fiscal Year 2017 to a Fiscal Year 2018 target.

These shifts and maneuvers have received mixed reception in industry. On the one hand, several industry officials with a deep perspective on the T-X program's evolution said the risk of "over-designing" an aircraft and system would have gone up had the Air Force not updated the requirements as time went on. Others said they see risk in a lack of firm schedules and requirements, at times opining about the need for a complete program restart. However, the bulk acknowledged that the government dialogue with industry is occurring and remains essential, although as one might expect, delays and incremental changes in thresholds and objectives that characterize contemporary defense contracting have added up.

Nearly all consulted said they viewed the evolved schedule and requirements as resulting in part from the Air Force's changing acquisition approach. As always, companies must therefore do a bit of guessing on their own research and development dime. Uncertainty is a factor that the Defense Department must seek to control if it wants industry to keep spending its own research dollars on preparing proposed T-X solutions as well as lean into new, beneficial uses of T-X in the future.

On average, industry has a sense that the contest has evolved from a focus on performance aspects of the T-X system to a rigid focus on schedule and keeping risk low. Even with some monetary incentives for better contract performance, a few hundred million dollars amounts to a very small amount when considering the T-X program will pay out many billions of dollars in the coming years.⁵³ Government must consider this carefully and continue to ensure acquisition goals are clearly and holistically represented and not misinterpreted.

Conclusion

The T-X program must succeed, as it represents the foundation on which core Air Force missions are based. Leadership is keenly aware that every year the T-38 remains in service, sustainment costs will surge, while fifth generation aviators will not receive an optimum foundation of skills in pilot training. A simple aircraft replacement for the T-38 is not the goal. A successful T-X acquisition must balance the competing demands of both procurement and operations and sustainment bow waves to best serve the long-term needs of the Air Force's most-precious resource: Airmen. The fifth generation force structure will only be as good as the individuals who operate, maintain, and support its employment for generations to come. Consequently, both government and industry must pursue a T-X system that essentially transforms pilot training to meet the requirements of combat aviation in an era of the information-infused "combat cloud." At the same time, the enduring nature of the rapid-paced, high-demand training pipeline for novice aviators necessitates a high-use, durable, and supportable trainer aircraft within the T-X system. The Air Force clearly wants to avoid a drawn-out timeline using a process that is either unengaged with industry or risks a legal protest by the losing bidder(s). An aggressively managed and transparent acquisition process is vital. A rich dialogue between government and industry remains essential. To date, Air Force officials and industry participants have indicated that a healthy dialogue

is occurring. Along this course, government must work to build industry confidence with clarity of technical requirements and intent to gain a superior industry response to the T-X request for proposal. This also means fairly evaluating existing contenders with systems purpose-built for the competition.

In the time remaining, the Air Force can continue to work to get the APT FoS offering as right as possible by focusing on: meeting the highest performance demands for building fifth generation training; acquiring a total training enterprise, not simply an aircraft; further developing OMS requirements and beneficial LVC standards; and pursuing value with a regard for savings across the T-X program's life cycle.

What is not in dispute is that the T-38 replacement must get into the force soon. The Air Force is understandably protecting its planned priority acquisitions: B-21, F-35, and the KC-46. Any delays to the T-X effort at any stage could jeopardize the project. Requirements advocates, acquisition specialists, and industry officials must continue to watch the clock with a regard for urgency, as the window to procure T-X grows narrower as other acquisition priorities grow. Beyond that window, the Air Force's ability to produce the most-effective pilot, while simultaneously capturing numerous cost efficiencies, will deteriorate rapidly. The next few months are crucial for fine-tuning the offering to ensure the selection yields the most-effective Advanced Pilot Training Family of Systems. ★

Footnotes

- 1 Air Force Materiel Command, "Advanced Pilot Training Schedule" chart, Wright-Patterson AFB, Ohio, Aug. 11, 2016, <https://www.fbo.gov/index?s=opportunity&mode=form&id=8cacbf513fb4c944764d6e9dbed4c60f&tab=core&tabmode=list&> (accessed October 2016).
- 2 Ibid.
- 3 Air Education and Training Command, "Advanced Pilot Training (APT T-X) Concept of Operations," Joint Base San Antonio-Randolph, Texas, May 6, 2016, 6, <https://www.fbo.gov/index?s=opportunity&mode=form&id=8cacbf513fb4c944764d6e9dbed4c60f&tab=core&tabmode=list&> (accessed October 2016).
- 4 IHS Jane's Fixed Wing Military Aircraft Database, "Northrop T-38 Talon," <http://www.janes.com> (accessed October 2016).
- 5 Ibid.
- 6 "Advanced Pilot Training (APT T-X) Concept of Operations," 6.
- 7 Mark Thompson, "Costly Flight Hours," *Time*, April 2, 2013, <http://nation.time.com/2013/04/02/costly-flight-hours/> (accessed October 2016).
- 8 Amy McCullough, "Alternatives to T-38," *Air Force Magazine Daily Report*, Sept. 14, 2010, <http://www.airforcemag.com/DRArchive/Pages/2010/September%202010/September%2014%202010/AlternativestoT-38.aspx> (accessed October 2016).
- 9 McCullough, "Questions Remain About T-X," *Air Force Magazine Daily Report*, Feb. 25, 2013, <http://www.airforcemag.com/DRArchive/Pages/2013/February%202013/February%2025%202013/QuestionsRemainaboutT-X.aspx> (accessed October 2016).
- 10 James' comments available online at: <http://www.defense.gov/News/Transcripts/Transcript-View/Article/911083/departments-of-defense-press-briefing-by-secretary-james-and-gen-goldfein-on-the>. Air Force Chief of Staff Gen David L. Goldfein also spoke at the Aug. 10, 2016, briefing.
- 11 Sig Christenson, "Air Force is Losing Pilots, and the Headwind is Getting Worse," *San Antonio Express-News*, Sept. 26, 2016, <http://guam.stripes.com/news/air-force-losing-pilots-and-headwindgetting-worse#sthash.7AybkMSQ.dpbs> (accessed October 2016).
- 12 Ibid.
- 13 McCullough and John A. Tirpak, "Funding a New Trainer," *Air Force Magazine Daily Report*, March 12, 2014, <http://airforcemag.com/DRArchive/Pages/2014/March%202014/March%2012%202014/Funding-a-New-Trainer.aspx> (accessed October 2016).
- 14 "Advanced Pilot Training (APT T-X) Concept of Operations," 2.
- 15 Ibid, 5.
- 16 Ibid, 6.
- 17 Author's note: This \$16.3 billion figure comes from the draft RFP assessment of the program's estimated cost cap for RDT&E and procurement only, as of October 2016. The Air Force's updates to the RFP and documents pertinent to the T-X acquisition can be found at: <https://www.fbo.gov/index?s=opportunity&mode=form&id=5dbdf3be4d0d8f26909bb4d62fda6458&tab=core&tabmode=list&>
- 18 Air Education and Training Command, "Capability Development Document for Advanced Pilot Training T-X Family of Systems," Joint Base San Antonio-Randolph, Texas, October 13, 2015, 44. This \$28 billion projected life cycle O&S figure, contained in the CDD's program life cycle projections, tracks closely with guidelines laid out in the CAPE 2014 Operating and Support Cost-Estimating Guide (found here: http://www.cape.osd.mil/files/OS_Guide_v9_March_2014.pdf). CAPE estimates the average fixed wing aircraft procurement program will feature O&S costs around 63 percent of total program life cycle cost, according to the OSC-EG, with just 30 percent of total program costs spent on procurement and 7 percent on research and development over the total life cycle (see page 2-2 of CAPE guide).
- 19 Air Education and Training Command, "Advanced Pilot Training (APT) (T-X) Information Briefing Paper," Joint Base San Antonio-Randolph, Texas, Oct. 12, 2016.
- 20 "Advanced Pilot Training (APT T-X) Concept of Operations," 12.
- 21 Ibid, 6.
- 22 Lara Seligman, "Affordability Trumps Performance in Air Force Trainer Race," *Aviation Week*, Sept. 30, 2016, <http://aviationweek.com/platforms-propulsion/affordability-trumps-performance-airforce-trainer-race> (accessed October 2016).
- 23 Ibid.
- 24 Ibid.
- 25 Author background interviews, multiple aerospace industry and Air Force observers of T-X program, Arlington, Virginia, Oct. 10-15, 2016.
- 26 "Advanced Pilot Training (APT) (T-X) Information Briefing Paper."
- 27 Author background interviews, Air Force weapons school instructors and officials, Arlington, Virginia, October 2016.
- 28 Author's Note: This analysis attributed to data extrapolated from 2008-2012 flight hour costs cited in note seven; additional information provided by Air Force weapons school instructor, interview, Oct. 10, 2016.
- 29 Author background interview, Air Force fighter aircraft maintenance officers, Arlington, Virginia, Oct. 14, 2016.
- 30 "Advanced Pilot Training (APT T-X) Concept of Operations," 2.
- 31 Ibid.
- 32 Brian Everstine, "T-X Award to Focus on Simulator Capability," *Air Force Magazine Daily Report*, Sept. 16, 2015, <http://www.airforcemag.com/DRArchive/Pages/2015/September%202015/September%2016%202015/T-X-award-to-focus-on-simulator-capability.aspx> (accessed October 2016).
- 33 Ibid.
- 34 "Advanced Pilot Training (APT T-X) Concept of Operations," 5.

Footnotes

35 Ibid, 9.

36 Ibid, 12.

37 Air Force Materiel Command, "System Specifications for the Advanced Pilot Training (APT) Program Ground Based Training System," Wright-Patterson AFB, Ohio, 11. This is Section J, Attachment 4 of the T-X draft request for proposal posted on Sept. 30, 2016, and available at:
<https://www.fbo.gov/index?s=opportunity&mode=form&id=8cacbf513fb4c944764d6e9dbed4c60f&tab=core&tabmode=list&>
(accessed October 2016).

38 Marc V. Schanz, "Inverting the Simulation Paradigm," *Air Force Magazine Daily Report*, Feb. 17, 2015,
<http://www.airforcemag.com/DRArchive/Pages/2015/February%202015/February%2017%202015/Inverting-the-Simulation-Paradigm.aspx>
(accessed October 2016).

39 Northrop Grumman Corporation, "Photo Release—Northrop Grumman Marks 50th Anniversary of T-38 Talon First Flight," April 13, 2009,
http://www.globenewswire.com/newsarchive/noc/press/pages/news_releases.html?d=162962
(accessed October 2016).

40 IHS Jane's, "Northrop T-38 Talon."

41 Deborah Lee James, "Meet the Air Force's New Acquisition System," *Defense One*, Jan. 13, 2016,
<http://www.defenseone.com/ideas/2016/01/meet-air-forces-new-acquisition-system/125102/>
(accessed October 2016).

42 Ibid.

43 Ibid.

44 Air Force Materiel Command, "System Specification for the Advanced Pilot Training (APT) Program Aircraft System," Wright-Patterson AFB, Ohio, June 27, 2016, 83. This is Section J, Attachment 3 of the T-X draft request for proposal issued on July 26, 2016, and available at:
<https://www.fbo.gov/index?s=opportunity&mode=form&id=8cacbf513fb4c944764d6e9dbed4c60f&tab=core&tabmode=list&>
(accessed October 2016).

45 "System Specification for the Advanced Pilot Training (APT) Program Aircraft System," 83.

46 Ibid.

47 IHS Jane's, "Northrop T-38 Talon."

48 "Advanced Pilot Training (APT T-X) Concept of Operations," 13.

49 Air Force Materiel Command, "Advanced Pilot Training (APT) Family of Systems Requirements Matrix," Wright-Patterson AFB, Ohio, March 17, 2015, 10,
https://www.fbo.gov/index?s=opportunity&mode=form&tab=core&id=ed3e2590221a5d4b365bd242ebc14540&_cview=0
(accessed October 2016).

50 "System Specification for the Advanced Pilot Training (APT) Program Aircraft System," 11.

51 Author's note: The Air Force is posting updates and documents pertinent to the T-X acquisition at:
<https://www.fbo.gov/index?s=opportunity&mode=form&id=5dbdf3be4d0d8f26909bb4d62fda6458&tab=core&tabmode=list&>

52 John A. Tirpak, "Surfing the Bow Wave," *Air Force Magazine Daily Report*, Sept. 20, 2016,
<http://airforcemag.com/DRArchive/Pages/2016/September%202016/September%2020%202016/Surfing-the-Bow-Wave-.aspx>
(accessed October 2016).

53 Author's note: These observations are based on comments made in a series of author background interviews with Air Force and aerospace industry observers, Arlington, Virginia, Oct. 10-15, 2016.

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