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Report to the Committee on Armed Services, House of Representatives

May 2023

ADVANCED PILOT TRAINER

Program Success Hinges on Better Managing Its Schedule and Providing Oversight

GAO-23-106205

GAO Highlights

Highlights of GAO-23-106205, a report to the Committee on Armed Services, House of Representatives

May 2023

ADVANCED PILOT TRAINER

Program Success Hinges on Better Managing Its Schedule and Providing Oversight

Why GAO Did This Study

The Air Force's Advanced Pilot Trainer program intends to replace the T-38 trainer jet, which is increasingly expensive to maintain and not reflective of modern fighter jets and other aircraft. The Advanced Pilot Trainer is behind schedule, increasing strain on Air Force resources as it maintains aging aircraft while developing the new aircraft.

A House report included a provision for GAO to assess the Advanced Pilot Trainer program. This report examines (1) any development challenges the program is facing, (2) the program's schedule targets and any risks to those targets, and (3) manufacturing plans for the aircraft.

To conduct this work, GAO assessed the extent to which the Air Force has developed and tested key technologies against program objectives. GAO reviewed the program's schedule and compared it to baseline estimates and GAO's best practices for schedules. Lastly, GAO assessed the program's manufacturing plans against federal regulations and DOD policy. GAO interviewed DOD and Air Force officials and contractor representatives.

What GAO Recommends

GAO is making two recommendations to the Air Force to (1) ensure the program conducts a risk assessment that incorporates risks of overlapping development, testing, and production phases, and (2) make a plan for determining under what conditions it would accept production work completed prior to contract delivery. DOD concurred with our recommendations.

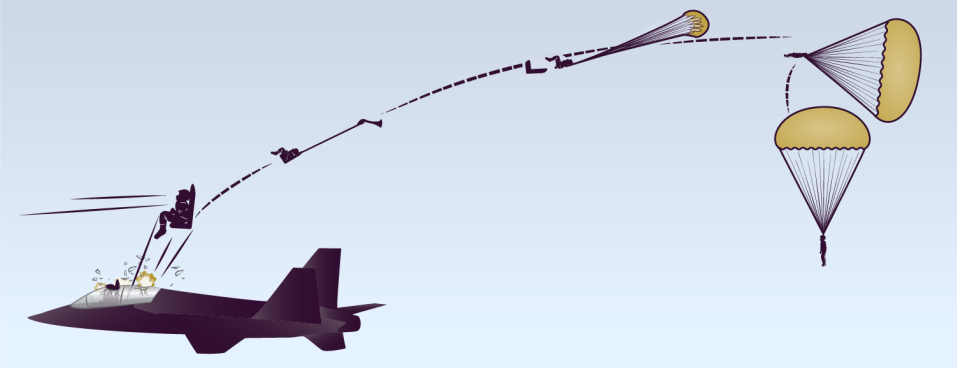
View GAO-23-106205. For more information, contact Jon Ludwigson at (202) 512-4841 or ludwigsonj@gao.gov.

What GAO Found

To train its pilots, the Air Force uses an aircraft designed especially for this purpose—the T-38 trainer jet. However, this trainer jet is more than 60 years old. Since 2011, the Air Force has been developing a trainer jet and flight simulator package, known as the Advanced Pilot Trainer, to replace the T-38 trainer jet. In late 2016, the contractor completed two prototype aircraft. The Air Force signed a contract in September 2018 for the development of the new trainers.

The Air Force has yet to resolve significant issues with the Advanced Pilot Trainer, including with its escape system and other components critical to achieving requirements. For example, the escape system—including the canopy fracturing system—does not yet meet safety standards. Therefore, the Air Force will not yet allow pilots to fly the test aircraft. Officials said the Air Force can resolve all of these issues, but it will likely take several years.

GAO Illustration of the Advanced Pilot Trainer Escape System



Source: GAO figure derived from Air Force and Douglas Aircraft information. | GAO-23-106205

The Advanced Pilot Trainer is nearly 10 years behind its initial estimate. In January 2023, the contractor developed a new schedule to reflect recent delays. However, according to Air Force program officials, this new schedule is also optimistic, relying on favorable outcomes not supported by past performance. In January 2023, the Air Force conducted a schedule risk assessment but did not assess two key risks. One of these risks is overlap between key program phases, which magnifies the cost and schedule impact of potential issues discovered during testing. Cascading delays increase reliance on the T-38 trainer or fighter jets for training, both of which are costly options.

Delays have also affected contractor decisions regarding manufacturing, with implications for the Air Force's quality assurance, which GAO refers to as oversight. Given development delays, the Air Force has not yet ordered aircraft beyond five initial test aircraft. But, the contractor began producing parts in March 2022 and intends to begin assembling aircraft in early 2024. The Air Force has not ordered production aircraft, so its traditional means of overseeing aircraft production is not viable, reducing confidence that this work will meet not-yet-established contract specifications. With limited oversight of production prior to ordering aircraft, the Air Force does not have a plan for determining under what conditions it would accept production work completed prior to contract delivery.

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Abbreviations

APT	Advanced Pilot Training
DCMA	Defense Contract Management Agency
DOD	Department of Defense
FAR	Federal Acquisition Regulation

U.S. GOVERNMENT ACCOUNTABILITY OFFICE
441 G St. N.W.
Washington, DC 20548

May 18, 2023

The Honorable Mike Rogers
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Air Force first flew its current training jet—the T-38—more than 60 years ago. It is increasingly expensive to maintain and is no longer reflective of modern combat aircraft. In 2011 under its Advanced Pilot Training (APT) program, the Air Force began pursuing a new training system that includes new aircraft and simulators, to better prepare pilots to fly the latest generations of aircraft, such as the F-35. The APT program has experienced significant delays, which increases strain on Air Force resources, while the program continues development and procurement of the APT system.

A House report related to a bill for the National Defense Authorization Act for Fiscal Year 2022 contained a provision for GAO to examine the APT program.[1] This report examines (1) what development challenges, if any, the APT program is facing; (2) the APT program's cost and schedule targets as well as any risk associated with meeting those targets, and (3) manufacturing plans for the APT aircraft.

To conduct our work, we assessed the extent to which the Air Force has developed and tested the system's key technologies against program objectives. We reviewed the APT program's cost and schedule estimates following recent changes to the schedule and compared these to its initial estimates. We also reviewed the program's January 2023 schedule risk assessment and compared it to schedule best practices we identified in prior work.[2] Lastly, we assessed the APT program's manufacturing plans in comparison with Department of Defense (DOD) policy. For each objective, we spoke with senior program officials, experts identified by the program office with knowledge related to the program's technological challenges, and senior contractor representatives. We removed content

[1]H.R. Rep. No. 117-118, at 60-61 (2021).

[2]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules,* GAO-16-89G (Washington, D.C.: December 2015).

that representatives from The Boeing Company identified as proprietary. For additional details on our scope and methodology, see appendix I.

We conducted this performance audit from August 2022 to May 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

The APT aircraft, known as the T-7A Red Hawk, and simulators are anticipated to improve pilot training and close the gap between current trainer aircraft and modern fighters and bombers, such as the F-22, F-35, and B-2. The Air Force is also planning for the aircraft and the simulators to work together to create a more complex and complete training experience. Figure 1 shows one of the contractor's two prototype aircraft.

Figure 1: T-7A prototype aircraft

Source: ©The Boeing Company. | GAO-23-106205

Following the development of initial program documentation and after delays stemming from Air Force funding and prioritization decisions, in September 2018, the Air Force awarded The Boeing Company (the contractor) an indefinite delivery contract estimated to be worth up to $9.2 billion to develop and build the T-7A aircraft and associated simulators.[3] The Air Force then awarded the contractor an $813 million fixed-price incentive and firm-fixed-price order for aircraft and simulator

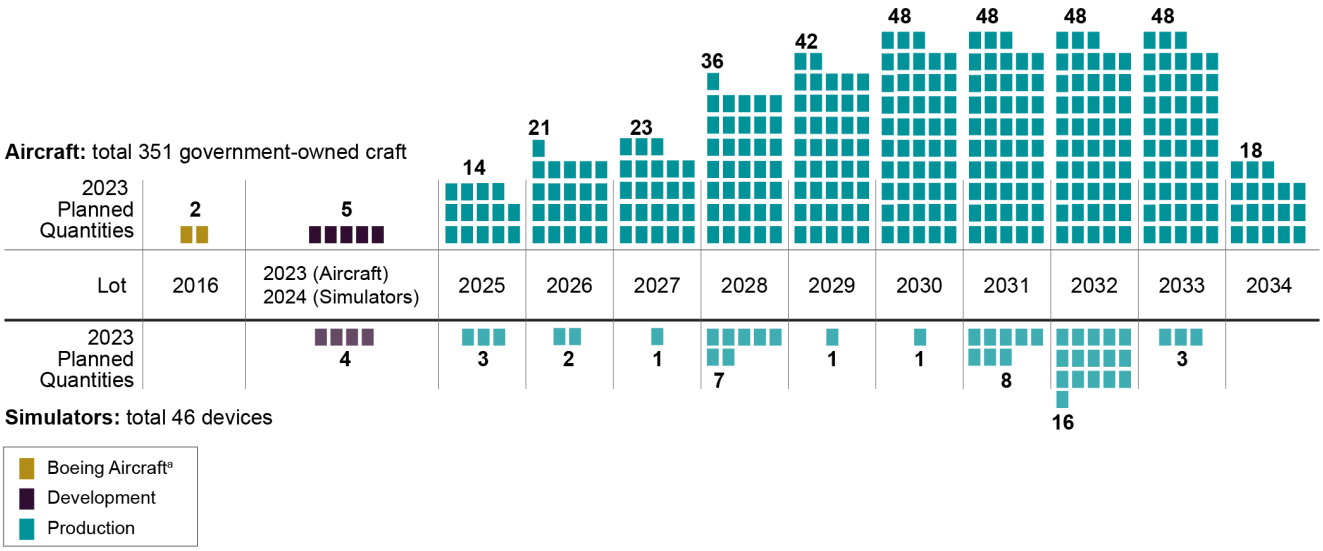
[3]An indefinite delivery/indefinite quantity contract provides for an indefinite quantity, within stated limits, of supplies or services during a fixed period. The government places orders for individual requirements, such as for aircraft. Federal Acquisition Regulation (FAR) 16.504(a).

development, among other things.[4] The contractor has produced several aircraft to help inform program decision-making. In anticipation of the APT program, the contractor developed two prototype aircraft, first flown in late 2016, to enable it to conduct initial testing and identify any potential issues early on. As part of the development order, in 2018, the Air Force ordered five developmental (test) aircraft with which it plans to conduct government-led developmental and operational testing. As of February 2023, the contractor had largely completed assembling these five aircraft.

The indefinite delivery contract allows for the fixed-price ordering of up to 473 aircraft and 120 simulators. Using this contract, the Air Force plans to order 346 aircraft and 46 simulators, among other items, with an estimated cost of $7.3 billion. Once the program holds a production decision, the program plans to place orders for specific lots of aircraft and simulators. The indefinite delivery contract identifies up to 11 different aircraft production lots, and DOD's budget estimate for fiscal year 2024 identifies a unit cost of $21.8 million, which includes aircraft, simulator devices, and spares. Figure 2 illustrates the planned procurement of 351 total aircraft and 46 simulators across multiple production lots.

[4]Under fixed-price incentive contracts, the contractor is incentivized to control costs since the contractor's profit is linked to actual performance. FAR 16.403-1(a). Fixed-price incentive contracts are appropriate when a firm-fixed-price contract is not suitable and when the contractor's portion of cost responsibility will provide a positive incentive for effective cost control and performance. FAR 16.403(b)(1), (2).

Figure 2: Production Plans for the Advanced Pilot Trainer



Source: GAO analysis of Air Force information. | GAO-23-106205

[a]Boeing aircraft are excluded from the count of 351 development and production aircraft.

Aircraft Assembly

The contractor intends to build the APT aircraft using an innovative manufacturing method expected to provide certain benefits for production and sustainment. This method, referred to as full-size determinant assembly, enables suppliers to deliver digitally engineered parts with holes precisely and accurately drilled at connection points. This process eliminates the need for manual drilling for tens of thousands of fasteners on each aircraft, saving significant resources and reducing drilling mistakes and nonconformities by approximately 98 percent as estimated by the contractor. To execute full-size determinant assembly, the contractor and key subcontractors design and manufacture aircraft components to very specific dimensions. The contractor said it successfully built the test aircraft using this process. Specifically, for the test aircraft built to date, contractor officials told us that this manufacturing method reduced assembly hours by 80 percent, and increased production quality by 50 percent.

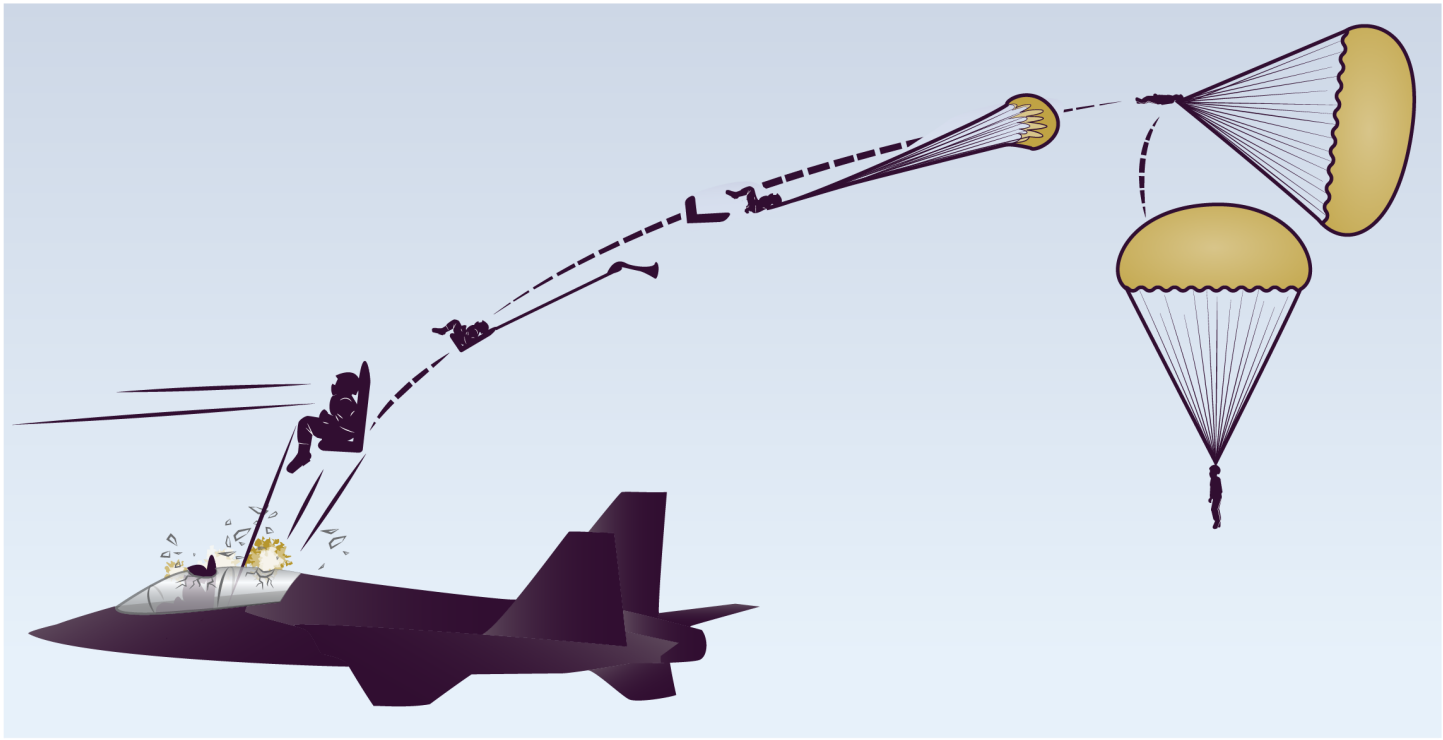
Aircraft Escape Systems

Many military aircraft are equipped with escape systems to ensure that pilots can safely eject from the aircraft in the event of an emergency. An aircraft's escape system includes an ejection seat that must safely leave the in-motion aircraft. In some aircraft, the system is designed to remove

the entire canopy, the portion of the aircraft used to enter and exit the aircraft, as well as the canopy glass. Other aircraft, including the APT trainer jet, use systems that fracture the canopy glass and eject the pilot through the opening. Aircraft escape systems must meet a variety of military standards for aircrew safety when ejecting.

For the APT trainer jet, when a pilot or instructor initiates an ejection sequence, a blast cord attached to the canopy glass explodes upward to create a hole in the canopy. Following the blast, several events are to occur in a precise sequence to ensure that the ejection seats propel out of the aircraft using small rockets. After ejecting from the aircraft, software determines when to deploy the parachute and separate the seat from the pilot. Figure 3 illustrates the APT's escape system.

Figure 3: GAO Illustration of the Advanced Pilot Trainer Escape System



Source: GAO figure derived from Air Force and Douglas Aircraft information. | GAO-23-106205

The Air Force evaluates escape system elements in a variety of ways, including using sled tests. During these sled tests, officials affix a cockpit to a sled on horizontal rails, place an instrumented manikin in the seat,

propel the cockpit down the track to simulate forces experienced by the aircraft, and then explode the canopy and launch the seat from the sled.[5] According to program officials, these sled tests are both expensive and logistically complex, but they simulate an ejection sequence to gather important test data without risking human life or loss of aircraft.

Airworthiness Certification

Airworthiness refers to the ability of an aircraft to safely attain, sustain, and complete flight in accordance with approved usage limits.[6] Before Air Force pilots can fly the APT aircraft, even for testing, the program must receive a Military Flight Release by demonstrating that (1) the aircraft complies with airworthiness standards, and (2) all known risks are acknowledged and accepted at an appropriate level. The Air Force's Director for Engineering and Technical Management, who is the service's airworthiness authority, makes the final airworthiness determination. The Air Force also has the option of awarding limited Military Flight Releases under certain conditions.

To obtain a Military Flight Release, the APT must meet an updated escape system airworthiness requirement. Prior to 2016, this requirement stated that the probability of incapacitating major injury can be no more than 5 percent. In 2016, the Air Force revised the requirement to include that the probability of moderate injuries to the pilot, including concussion, when using the escape system should also be 5 percent or less.

Ground-Based Training Systems (Simulators)

The APT Ground-Based Training Systems comprise a number of different types of simulator devices. These devices range from a desktop computer linked to realistic stick and throttle controls, to a full-featured aircraft simulator, referred to as the weapon system trainer, which provides the pilot with full 360-degree visibility. Figure 4 shows the weapon system trainer.

[5]Because the APT aircraft is designed to accommodate both a pilot and an instructor, program officials said each sled test involves two ejections—one for the forward occupant, and one for the rear occupant.

[6]According to Department of Defense Directive 5030.61, airworthiness approval affirms that the appropriate tenets of the airworthiness process are met, the air system was assessed against the required airworthiness standards, and any risks to aircrew, ground crew, passengers, or third parties have been accepted by the appropriate authorities.

Figure 4: Advanced Pilot Trainer Weapon System Trainer

Source: The Boeing Company. | GAO-23-106205

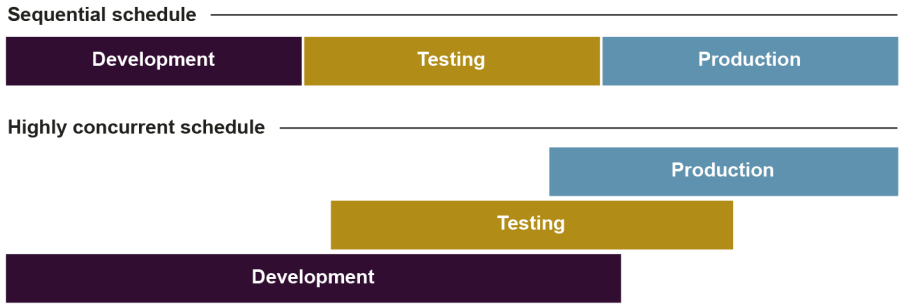
Simulators enable pilot trainees to participate in realistic mission scenarios and gain increasing levels of proficiency with aircraft controls, targeting, and other combat-related competencies without the risks and costs of flying the aircraft. The Ground-Based Training Systems plan to include both hardware and software that enables pilot trainees in the simulators to work simultaneously with pilots in the APT aircraft in real time. This represents a new capability for the Air Force's training systems, and the Air Force plans to house the APT simulators at multiple training bases.

Risk Associated with Concurrency

DOD programs using the major capability acquisition pathway typically follow a sequential process aimed at reducing risk before advancing to the next step of the acquisition process.[7] First, during the development phase, engineers create prototypes that undergo extensive testing. Then, once the government has assurance that it can meet cost, schedule, and quality targets, the program makes a decision to enter the production phase.

In our work over the last several decades, we have noted that high levels of concurrency, or overlap, among the development, testing, and production phases of an acquisition have led to significant cost and schedule growth, as well as performance shortfalls.[8] Figure 5 illustrates the sequential approach compared to a highly concurrent acquisition.

Figure 5: Sequential Schedule versus a Highly Concurrent Schedule



Source: GAO analysis. | GAO-23-106205

Producing aircraft before successfully completing testing increases the likelihood that aircraft that have already been built may require retrofitting to accommodate necessary design changes to overcome issues found during testing. This could thereby increase the cost and delay the schedule. A well-managed program can mitigate the risks of a schedule

[7]DOD Instruction 5000.85, Major Capability Acquisition (Aug. 6, 2020) (incorporating change 1, Nov. 4, 2021). Released in August 2020 and updated in November 2021, this instruction established the policy and prescribed procedures that guide acquisition programs using the major capability acquisition pathway. Within this pathway, programs generally proceed through a number of phases.

[8]See, for example, GAO, *Navy Shipbuilding: Past Performance Provides Valuable Lessons for Future Investments,* GAO-18-238SP (Washington, D.C.: June 6, 2018); and *Joint Strike Fighter: DOD Actions Needed to Further Enhance Restructuring and Address Affordability Risks,* GAO-12-437 (Washington, D.C.: June 14, 2012).

with some concurrency between two phases, such as development and testing, while potentially meeting cost, schedule, and performance targets. However, overlap between three major phases, such as development, testing, and production, can result in significant rework. This is more likely if developmental discoveries cause changes to the test plan and ultimately the aircraft itself.

Aircraft Oversight

The Air Force conducts quality assurance activities, which we call oversight for the purposes of this report, to determine whether contractors fulfilled their contract obligations pertaining to quality. The following provides a summary of relevant quality assurance policies.[9]

- **Federal Acquisition Regulation (FAR) part 46:** prescribes policies and procedures to assure that supplies (such as aircraft) and services acquired under a government contract conform to the contract's quality and quantity requirements, including provisions on inspection and acceptance. Under the terms of inspection clauses, the government generally has the right to inspect and test supplies provided by contractors to meet the terms of the contract before accepting the supplies.
- **FAR 46.101:** defines acceptance as the act of an authorized representative of the government—in many Air Force cases, the Defense Contract Management Agency (DCMA)—by which the government assumes ownership of supplies provided by the contractor as partial or complete performance of the contract.
- **FAR subpart 46.5:** prescribes specific regulations on acceptance. FAR 46.501 states, among other things, that acceptance constitutes acknowledgement that the supplies or services conform to applicable contract quality and quantity requirements.
- **Defense Federal Acquisition Regulation Supplement subpart 246.5:** identifies DOD regulations related to certificates of conformance, including use of a certificate of conformance for critical aircraft safety items.

[9]For the purposes of this report, we use *oversight* as a direct substitute for *government contract quality assurance*. Government contract quality assurance means the various functions, including inspection, performed by the government to determine whether a contractor has fulfilled the contract obligations pertaining to quality and quantity. FAR 46.101. During our engagement, the Air Force and the Defense Contract Management Agency (DCMA) referred to their relevant quality assurance functions as part of their *surveillance*. DCMA Instruction 2303 implements the DCMA surveillance framework and surveillance activities.

- **DCMA Instruction 2101:** states that, among other things, it is DCMA policy to accept products and services provided by contractors when there is a basis of confidence that the products and services fulfill the terms and conditions of the contract. DCMA also has the responsibility, when delegated, to reject nonconforming products and services that do not fulfill the terms and conditions of a contract.

Because aircraft are complex and failure to build them properly could result in catastrophic loss of pilots or the aircraft, obtaining confidence that the aircraft meets contract requirements requires oversight of production throughout the building process. According to Air Force officials, it is more costly, invasive, and ineffective for the government to inspect an aircraft after it is complete compared to conducting oversight throughout the production sequence. Typically, the Air Force delegates responsibility for complying with the above federal and DOD regulations for accepting aircraft to DCMA.

When delegated responsibility, DCMA provides contract administration services for DOD buying activities and works with defense contractors to help ensure that they deliver goods and services on time, at projected costs, and in accordance with performance requirements. DCMA works to identify quality deficiencies on Air Force aircraft at all points throughout the aircraft production process. DCMA oversees aircraft production by inspecting and testing the contractor's completed work and issuing requests for the contractor to correct any identified deficiencies.

A wide range of employees within DCMA performs these responsibilities, including administrative contracting officers, engineers, property administrators, quality assurance representatives, and government flight representatives. Government flight representatives approve contractor test flights, procedures, and crewmembers, and assure contractor compliance with DCMA guidance on contractor flight and ground operations, among other things.

Program Has Yet to Solve Four Key Development Challenges

The Air Force has yet to resolve significant issues with the escape system, flight software, simulator, and aircraft sustainment, which are all critical to the APT program achieving performance requirements. First, the escape system does not yet meet safety standards and the contractor will likely need to execute several more design iterations and tests to resolve the problems, according to program escape system experts. Second, the contractor stated that it will finish the flight control software this summer. However, Air Force experts estimate the contractor will need several additional software versions before the software is

complete. Third, Air Force officials believe that the simulator is on track to meet requirements but the contractor has yet to begin building the software needed to connect live trainer jets with simulators in real time. Lastly, the contractor has provided the Air Force with one-third of the expected sustainment data, which could hinder the Air Force's ability to conduct the number of flights necessary to achieve its test plan. While some of these issues are typical when developing an aircraft, the program's escape system challenges and coordination between the simulator and aircraft are unique to this program.

Escape System Does Not Yet Meet Safety Standards

The APT's escape system does not yet meet DOD and Air Force standards for pilot safety, which is delaying aircraft testing. To improve the escape system, the Air Force identified several areas in which ejecting from the aircraft poses unacceptable risks to pilots, including the risk of concussion upon ejection, body acceleration that could result in spinal injury, and eye and neck injury. As a result, the Air Force has yet to approve a full or limited Military Flight Release for its pilots to fly the APT aircraft. In turn, the Air Force has declined to accept the five test aircraft and begin the government-led developmental test program that uses Air Force pilots.

The APT includes requirements aimed at ensuring that a broad range of pilot or instructor body types can safely eject from the aircraft. In general, larger body types were less prone to injury in these types of tests than smaller body types. However, test results for even the largest manikin barely meet the Air Force's safety standard, with risks being greater for average-to-smaller occupants.

The Air Force conducted an escape system test in February 2023 and based on the results of that test, the APT program intends to seek approval from the Air Force airworthiness authority for a limited Military Flight Release. A limited flight release would allow the Air Force to begin flight-testing while it fully resolves remaining escape system issues. According to program officials, even if granted a limited Military Flight Release, the Air Force is likely nearly 2 years away from fully demonstrating that its escape system design meets safety standards, based on the current test schedule.

Air Force engineers we spoke with who work on the escape system, as well as independent experts, expect that a series of relatively minor design improvements—that the program plans to evaluate in further testing—will result in a fully approved and safer system. However, it has taken more than 15 months for the Air Force to get results from the

previous test, analyze the results with the contractor, gain agreement from the contractor to implement necessary design changes, and re-test the escape system. According to program officials, this delay resulted in part from disagreement with the contractor over how to apply standards for the probability of injury. To help resolve these issues, the Air Force awarded Boeing a contract totaling $9 million to study ways to improve escape system performance. Program officials said this contract provided funding for four sled tests. The Air Force tested some design changes for the APT escape system in its February 2023 test, but program officials said the system, in order to meet airworthiness criteria, needs at least seven additional tests to achieve confidence in the system. These seven tests include the three remaining tests funded under the study and four more that the contractor is planning to conduct.

Testing to date revealed that the escape system poses a high risk of concussion or spinal cord injuries to ejecting pilots at three key phases of the ejection process. While the February 2023 sled test showed some progress in reducing these risks, the Air Force and the contractor need to make additional improvements at three key points in the sequence to meet safety standards, as discussed below.

1. **Activation of the canopy fracturing system.** The February 2023 test found that changes to the canopy fracturing system may reduce the risk of injury to pilots from activating the system. According to escape system experts, activation of the canopy fracturing system causes significant pressure within the cockpit known as blast overpressure. Prior to the February 2023 test, the Air Force's test results showed this pressure to be at levels high enough to cause a concussion in more than 20 percent of escapes, well above the 5 percent threshold. Figure 6 shows the APT ejection seat and the blast cord for the canopy fracturing system.

Figure 6: Advanced Pilot Trainer Ejection Seat and Canopy Fracturing System Blast Cord

Source: The Boeing Company. | GAO-23-106205

Contractor and Air Force officials told us there is little test data and few methods available for assessing pressure-induced traumatic brain injury in enclosed spaces (such as a cockpit). To gain more knowledge, the contractor commissioned an independent study in 2022, which noted that some relatively small design changes could have a significant impact on pilot safety. For example, the current design coils the blast cord directly over the pilot's head, which concentrates the blast in the most sensitive area of the cockpit. Air Force escape system experts said it was designed this way to reduce the possibility of very large chunks of the canopy remaining intact and hitting the ejecting pilot. In the February 2023 test, the Air Force reduced the amount of explosives in the blast cord, which significantly reduced the blast overpressure in the cockpit.

2. **Pilot ejection.** There remains a risk of canopy fragments hitting the pilot during ejection. In some tests, including the February 2023 test, large canopy fragments stuck to the test manikins as they passed through the exploded canopy. As the pilot enters the airstream, there is risk that the fragments will dislodge and injure the pilot or remain on the pilot and cause the seat to rotate unsafely in the air.
3. **Parachute deployment.** There continue to be risks involving sudden body accelerations after ejection during deployment of the parachute. Specifically, the seat must be in perfect alignment when the parachute

is deployed so that it pulls the pilot from the seat only when the pilot's spine is aligned with the force generated by the opening of the parachute. If the seat is not in perfect alignment, high g-forces could cause serious injury or death to the pilot. To address this, the Air Force and the contractor made some firmware updates to the ejection seat computing system that calculates its speed and altitude, and determines when deceleration is sufficient for pilot separation and deployment of the parachute. In the February 2023 test, these updates resulted in reduced body accelerations, but additional improvements continue to be needed.

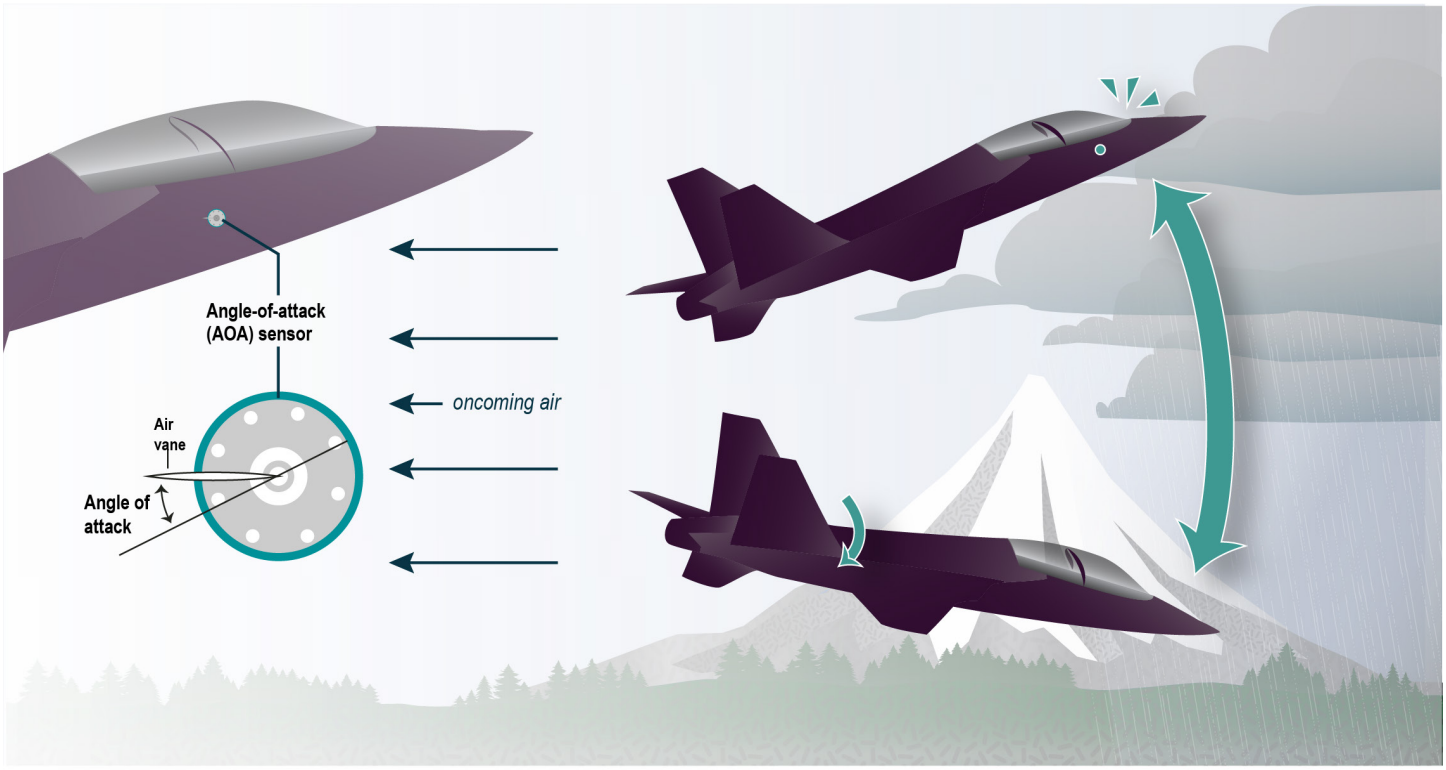
Flight Control Software Likely Needs More Development Than Planned

The Air Force and the contractor disagree on the maturity level of the flight control software. The contractor plans to complete the APT flight control software by mid-2023. However, Air Force software experts said that several additional software iterations will be required due to anticipated deficiencies found in flight testing.

Specifically, Air Force software experts said it is likely that the contractor will have to produce an additional five-to-six software iterations to address flight control deficiencies. This will be especially likely as the testing encompasses increasingly challenging aspects of flight. Air Force software experts estimated they could each take an additional 6 months to complete based on prior experience with this and other aircraft programs. This additional time could delay completion of the software more than 2 years beyond the estimated completion date, and could potentially disrupt flight-testing if required software changes are significant.

Early tests revealed issues with the aircraft's flight control software under some flight conditions. Specifically, APT program requirements state that the aircraft must be highly maneuverable at high angles of attack (i.e., 25 degrees). The angle of attack is the angle between the wing and the relative direction of oncoming air that corresponds to the direction of flight at a given moment. Thus, an aircraft generally experiences high angles of attack when the aircraft is climbing to higher elevations or diving to lower elevations. At high angles of attack, there is a greater chance of losing lift or stability. Figure 7 shows a simplified depiction of angle of attack.

Figure 7: Angle of Attack



Source: GAO analysis of Air Force information. | GAO-23-106205

Because modern aircraft are controlled electronically, the flight control software has a key role in determining aircraft maneuverability and other flight characteristics. A program engineer said that at high angles of attack, and especially at slower speeds, the APT aircraft experienced some unexpected airflow across the aircraft, which resulted in undesired wing movement. That engineer said it is difficult to anticipate flight qualities at high angles of attack either in wind tunnel testing or in computer modeling. Engineers also indicated that they believe they can improve the maneuverability of the aircraft through changes to the software, which could avoid aircraft redesign in this case.

Simulator on Track but Not Yet Complete

The contractor is making progress developing the simulators but faces some ongoing technical challenges. There are two significant issues remaining with the simulators. First, issues with the high-resolution projectors affect their ability to meet performance specifications for the weapon system simulators. These specifications relate to color and visual

clarity, among other characteristics. For example, clusters of illuminated but unresponsive pixels can hinder identification of small targets and render night vision scenes unusable. Program officials said this issue is primarily due to how projector prototypes are built. They indicated that the subcontractor building the projector expects to correct the issues once it initiates production in the proper dust- and contaminant-free environment in 2024.

Second, the contractor has yet to complete the development of the software that will enable real-time coordination between the APT aircraft and simulators. The contractor plans to deliver the final version of this software in mid-2023. Program officials said this version will connect previously developed flight control software with aircraft mission, navigation, and communications systems, and will enable construction of virtual training targets for use by either the simulator operators or pilots in actual aircraft.

Key Sustainment Data Not Available

The Air Force notified the contractor that it has not met contract time frames for providing an aircraft bill of materials—the list and quantity of parts used to build and maintain the aircraft. In July 2022, the Air Force sent the contractor a letter disapproving its bill of materials submission as incomplete. The Air Force's APT acquisition strategy calls for maximum organic, or in-house sustainment. However, according to the notice, the contractor has submitted about one-third of the bill of materials as of January 2023—more than 3 years later than specified in the contract. Additionally, these officials noted that the contractor redacted some information needed to conduct in-house sustainment. Contractor officials said some suppliers were not initially on contract and that they are updating the program office periodically. Without comprehensive sustainment data, as determined by the Air Force, the program may be reliant on the contractor for general maintenance and repairs. In April 2022, we found similar issues on the F-35 aircraft, for which the government does not have sufficient data to support its sustainment planning and execution, resulting in heavy reliance on the contractor.[10]

Additionally, Air Force officials indicated they need sustainment information to maintain the five test aircraft it will be using to conduct flight-testing. For example, without the bill of materials, the Air Force cannot determine specific support equipment needed for maintenance, or

[10]GAO, *F-35 Sustainment: DOD Faces Several Uncertainties and Has Not Met Key Objectives,* GAO-22-105995 (Washington, D.C.: Apr. 28, 2022).

whether the equipment it needs is common across different aircraft types or unique to the APT aircraft. Further, Air Force sustainment experts said they need the bill of materials to manage obsolescence of parts across the entire supply chain. As we found in September 2017, without information on which companies' parts are used in an aircraft, it is difficult for the Air Force to manage obsolescence.[11]

Air Force officials told us that there is still time for the program to receive the information and plan for sustainment, but expressed concern because there has been little progress over the last year. Moreover, maintenance issues could further delay flight testing, which is already proceeding more slowly than expected in part due to issues with aircraft maintenance and availability.[12]

APT Program Is Nearly 10 Years Late and Failure to Execute Remaining Schedule Could Increase Air Force Costs

The Air Force is nearly 10 years behind its initial schedule estimates for the APT program and continues to experience delays. Following a June 2022 schedule breach, the Air Force received a new schedule from the contractor in January 2023. However, program officials told us this new schedule is likely optimistic since the schedule for several areas depends on favorable assumptions. Further, the Air Force conducted a schedule risk assessment on the contractor's schedule but it did not account for key risks. Even though the APT jet and simulator costs are currently fixed, the APT program delays will likely cost the Air Force nearly $1 billion due to the need to use more expensive fighter jets to train pilots and funding for unplanned upgrades to existing trainer aircraft. Additional delays to the APT program could exacerbate these and other costs.

New Schedule Remains Optimistic Following Breach

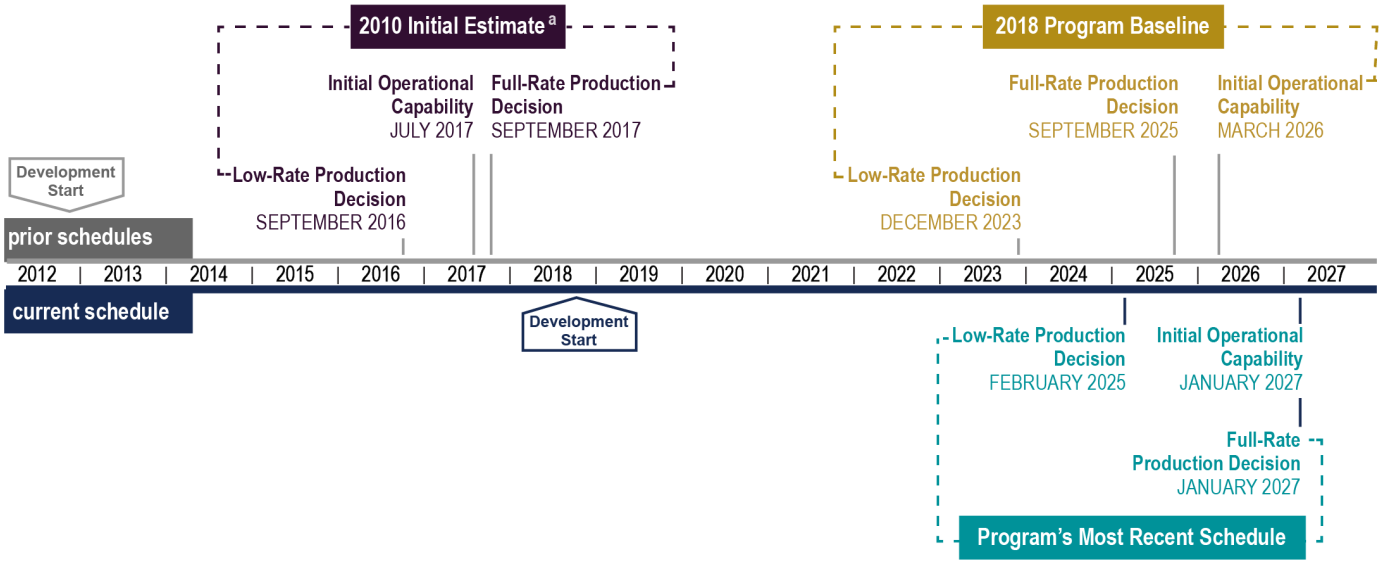
In June 2022, the APT program declared a schedule breach after determining that it would not be able to begin low-rate initial production by December 2023, as previously scheduled. The breach resulted in a 14- to 26-month delay in the planned low-rate initial production decision date, which the Air Force scheduled for February 2025. The Air Force is allowing for an additional 12 months of delay without declaring a breach by setting a latest acceptable low-rate initial production date of February 2026. In total, the Air Force will not be able to provide APT aircraft to its trainers until nearly 10 years after the initial estimate of 2017. Figure 8

[11]GAO, *Defense Supply Chain: DOD Needs Complete Information on Single Sources of Supply to Proactively Manage the Risks,* GAO-17-768 (Washington, D.C.: Sept. 28, 2017).

[12]We previously reported on the availability of 49 of DOD's aircraft. See GAO, *Weapon System Sustainment: Aircraft Mission Capable Goals Were Generally Not Met and Sustainment Costs Varied by Aircraft,* GAO-23-106217 (Washington, D.C.: Nov. 10, 2022).

illustrates the program's major milestones based on its initial estimates, its 2018 program baseline, and its most recent schedule following the June 2022 breach.

Figure 8: Advanced Pilot Trainer Prior Schedules Compared to Current Targets



Source: GAO analysis of Air Force documentation. | GAO-23-106205

[a]Dates are approximate based on a graphical representation of the program's timeline.

The contractor provided a new schedule to the program office in January 2023 that program officials consider optimistic. Program officials told us the contractor's schedule does not account for any delays during the remaining program development tasks, has an optimistic test flight schedule, and does not account for re-testing any test failures.

Development Delays

Resolving the developmental issues discussed earlier—such as the escape system, flight control software, and linking the simulators and aircraft for simultaneous training operations—could take longer than planned. For example, the Air Force states that they need at least seven more escape system tests to have confidence that the escape system meets performance specifications. While the Air Force plans to conduct sled tests every 3 months until the system is fully qualified, as previously noted, 15 months has passed since the last escape system test.

Test Flight Schedule

The contractor has not been able to execute its planned test flight schedule with the two prototype aircraft. Specifically, between October 2019 and February 2023, the contractor executed 42 percent of the 794 planned test flights due to weather, maintenance, and operations issues. Further, the contractor has been able to keep one prototype aircraft flying because it had to borrow parts from the other prototype aircraft.

The ability to complete test flights is critical to the timely achievement of the test schedule. While program officials expect the rate of testing to increase with the addition of five new test aircraft and better weather at the government test location, these officials anticipate that the Air Force will not be able to sustain the contractor's planned testing rate. Program officials told us that they will likely face challenges maintaining the aircraft, which could reduce aircraft availability below the rate assumed in the test schedule. Failing to achieve the planned testing rate will delay the testing schedule and the program's overall progress, or require the Air Force to enter production with less knowledge about the aircraft than planned because it lacks the data the missed flight tests were expected to provide.

Test Failures

Air Force officials told us that the contractor's schedule assumes that the APT program will achieve a very high success rate throughout the remainder of the development and testing phases. That is, the contractor's schedule includes little to no margin for failed tests, unscheduled software builds, potential escape system redesign, or other unexpected events. As such, any issues that the Air Force or contractor discover are more likely to lead to significant program delays. Further delays could cause the program to miss its new date for a production decision, thus pushing back the production and delivery of the aircraft.

Air Force Schedule Assessment Excluded Two Key Risks

In January 2023, the Air Force conducted a schedule risk assessment on the contractor's schedule, but its analytical technique did not assess the potential schedule impact of two key risks. A schedule risk assessment is a leading practice in which a statistical simulation predicts the level of confidence in meeting a program's completion date.[13] Results from the risk assessment identify high-priority risks and help the program determine appropriate levels of contingency. The program office's schedule risk assessment technique accounts for discrete activities and therefore does not account for two of the highest program risks, which are

[13]GAO-16-89G.

(1) overlap in the schedule between key acquisition phases, also referred to as concurrency, and (2) contractor management.

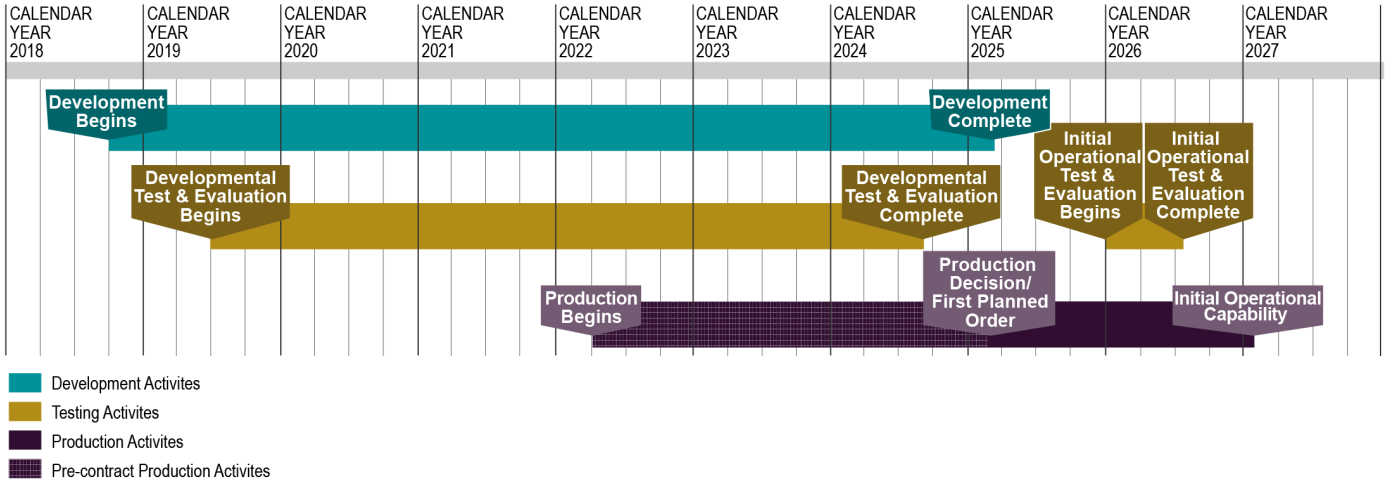
The APT program office conducts monthly schedule risk analyses to determine the likelihood that the program completion date provided by the contractor will occur on time. According to program officials, during these analyses, program schedule officials consult with subject matter experts to generate an optimistic, most likely, and pessimistic duration for dozens of activities. For example, if the activity involves reviewing test data, then the program applies durations that it has historically found are accurate for that specific type of activity. Scheduling officials then run simulations to estimate the most likely completion dates for key milestones and a level of confidence for the potential completion dates for the whole program.

However, the Air Force's method of conducting the schedule risk assessment does not factor in key risks that the program's leadership is aware of, namely risks from concurrency and contractor management.

Concurrency

The Air Force originally planned for a limited development phase for the APT program followed by four sequential test phases, and then production, but it now plans for all of these program phases to overlap, which adds significant risk to the schedule. For example, several developmental items are unlikely to resolve within the next year or longer. In addition, the contractor has started producing parts for the APT aircraft. While the contractor is producing these aircraft at its own risk, the Air Force may not be fully protected from potential issues and retrofit work resulting from the overlap of these key phases of the program. Figure 9 illustrates how the contractor and the Air Force are planning for these key program phases to overlap.

Figure 9: The Advanced Pilot Trainer Current Planned Schedule Is Highly Concurrent



Source: GAO analysis of Air Force documentation. | GAO-23-106205

Our prior work has shown that programs with concurrent schedules are more likely to experience poor program outcomes such as unexpected cost increases or schedule slips.[14] One key reason programs with concurrent schedules experience poor outcomes is that the overlapping schedule magnifies the impact of any issues. For example, if a program discovers an issue during testing, resolution of the issue could affect developmental designs, test plans, or require retrofitting of aircraft already in production, or all three.

Program officials told us that they do not believe that development and testing issues will result in significant changes to the airframe, which should limit the impact of an overlapping schedule. However, we previously reported that high levels of concurrency often lead to significant cost and schedule growth, performance shortfalls, and other adverse consequences.[15] For example, in June 2018, we found that the F-35 program would face an additional $1.4 billion in costs to retrofit aircraft because of building aircraft before fully testing them.[16] As of April

[14]GAO-12-437; and GAO-18-238SP.

[15]GAO-12-437.

[16]GAO- F-35, *Joint Strike Fighter: Development Is Nearly Complete, but Deficiencies Found in Testing Need to Be Resolved*, GAO-18-321 (Washington, D.C.: June 5, 2018).

2023, program officials said concurrency issues have not increased program costs.

Contractor Management

The Air Force's schedule risk assessment also did not account for any risk related to the Air Force's ability to resolve contract issues in a timely manner. The process of resolving developmental and test issues has already delayed qualification of the escape system by more than a year. For example, as previously discussed, the program's follow-up sled test did not occur until February 2023, 15 months after the previous test, which has significantly delayed the development of the escape system. Program officials told us that cooperation recently improved due to the Air Force's decision to fund an escape system study and additional sled tests. However, the Air Force required the contractor to plan for at least four additional sled tests at its own expense, which could result in a reversion back to previous levels of cooperation, according to program officials. Further, program officials told us there are several other areas of disagreement between the Air Force and the contractor, such as the provision of sustainment data.

Air Force program officials said that they expect what they call a tenuous relationship with the contractor to remain a key element of managing the program, especially as the contractor continues to lose money. Specifically, according to its September 2022 corporate earnings filing, the contractor has already recorded more than $1 billion in losses associated with the APT program. According to this filing, program delays manifest as financial losses for the contractor. The filing also states that the losses are driven by ongoing negotiations with suppliers, inflationary pressures, and design changes to the APT to solve technical issues or resulting from changes to the industrial base, among other reasons. Thus, based on differing interpretations of contract requirements to date, program officials said disagreements between the Air Force and the contractor may become more likely as the contractor builds the aircraft.

Our leading schedule assessment practices state that collecting comprehensive, anonymous, and unbiased risk data is key to conducting an accurate schedule risk assessment.[17] Without having the ability to include these two key risks, the current schedule risk assessment does not reflect potential delays that could result if these two risks are realized. Officials told us that they attempted to account for the development and concurrency risks by adding a buffer to their planned low-rate production

[17]GAO-16-89G.

decision date compared with the contractor's estimate. However, without assessing these risks and including them in the schedule risk assessment, the program is relying on its own estimated buffer rather than one grounded in statistical prediction based on an assessment of the likelihood of risks. According to our leading practices, analyzing all schedule risk using quantitative assessment is key to creating a reliable schedule.[18] Thus, without assessing these risks, the program does not know the likelihood of meeting its current low-rate initial production targets.

Additional APT Program Delays Could Increase the Air Force's Costs

While the APT program's contract costs are currently fixed at about $9 billion, its costs could increase if there are significant changes to the systems or if program delays persist. The APT program has largely fixed costs because the Air Force entered into fixed-price-type contracts for development and production. However, the Air Force faces some cost risk. Specifically, program officials told us that the Air Force will be at risk if it cannot order all 351 APT aircraft before the ordering period in the contract expires.

The Air Force is also paying for higher training costs than initially planned because of the APT schedule delays. In the early stages of the APT program, the Air Force planned to field the aircraft in 2017. The Air Force has already spent nearly $300 million to extend the service life of select T-38 Talons. This process of extending service life, reserved for jets that are in the worst structural condition, requires that engineers completely disassemble the aircraft and replace several parts and panels. A prior APT schedule delay caused the Air Force to add 10 T-38 aircraft to this program. Additionally, the Air Force is conducting a less intensive program to extend the life of 100 T-38s that are in better condition than the ones described above. If the Air Force conducts both of these programs to the extent that it is currently planning, it will likely spend a total of nearly $750 million to keep the legacy trainer fleet operational, and further delays to the APT program could increase this cost.

The Air Force determined that the T-38C does not meet the Air Force's needs to train its pilot population to operate modern military aircraft, and depends on non-trainer aircraft for this purpose, at a high cost. Based on an analysis of need, the T-38C lacks 12 capabilities required for pilot training, including high-altitude maneuverability, fly-by-wire controls, advanced air-to-air mission employment, autonomous formation systems,

[18]GAO-16-89G.

and the capacity to accommodate pilots of a wide range of sizes. To address these and other aspects of pilot training, the Air Force uses the F-22, which Air Force officials estimate costs more than $85,000 per flying hour, along with other fighter jets.[19] This cost is more than eight times what Air Force officials estimate the APT will cost per flying hour. While an Air Force training expert said the service does not track the cost of using combat aircraft to train new pilots, he expects the APT to reduce the strain on Air Force resources, including the availability of aircraft and additional training costs.

Contractor Has Begun Manufacturing Aircraft without a Delivery Order and Government Oversight

In early 2022, the contractor began producing APT aircraft parts and plans to begin assembling the first aircraft by early 2024, even though the Air Force has not yet placed any delivery orders for production aircraft. The Air Force does not plan to place an order for aircraft until it completes development currently scheduled for February 2025. The Air Force is responsible for assuring that any aircraft presented by the contractor meets contract specifications, but because there is no contract in place, the Air Force cannot use its previously negotiated quality management plan delegated to DCMA to assure compliance. The Air Force and DCMA have discussed how to provide oversight of production in this situation, but have been unable to establish a method for doing so that complies with legal constraints. With limited production oversight, the Air Force could face significant risk if it does not have assurance that these aircraft meet the future contract requirements.

The Contractor's Decision to Move Forward with Production Presents Schedule and Quality Risks to the Government

In March 2022, the contractor sent a letter to the Air Force stating that it began building certain APT aircraft parts. The letter also stated that it would like the Air Force to arrange for oversight of production.

Prior to receiving the letter, in January 2022, the Air Force sent a letter to the contractor emphasizing that the Air Force had no obligation to buy the aircraft assembled with those parts until it places a delivery order and that work done by the contractor must meet all requirements for current or future orders. While the contractor has begun production, according to current plans, the Air Force is not planning to place orders until at least February 2025—after it finishes development and a significant portion of the test program. Contractor representatives estimate that, during this time, the contractor will develop parts for and begin assembly of APT aircraft with its own funding. Government officials estimate that the

[19]The cost per flying hour of the T-38C is $9,021 and the estimated cost per flying hour of the APT will be $9,965. The cost per flying hour of the F-22 is $85,325.

contractor could complete between seven and 10 aircraft by the time the Air Force places an order. If the Air Force later orders production aircraft, the contractor may present for government acceptance the work it completed prior to the Air Force order.

The contractor's decision to move forward with building aircraft that it may provide to the government for acceptance presents the Air Force with significant risks. Contractor representatives told us that they started production because they are facing pressure to keep suppliers engaged to control manufacturing costs, given accumulating schedule delays and financial losses on the program. Even while the contractor is responsible for ensuring that any work completed prior to potential contract award conforms to future contract requirements, this arrangement presents risks to the Air Force:

- The Air Force has yet to finish the development phase of the program and begin the first government-led test phase. Therefore, there may be a significant number of changes to the test aircraft design before the low-rate production contract is awarded. All of these changes would have to be retrofit on any work completed in the meantime. While the bulk of the cost risk may fall on the contractor, the APT program may experience delays.
- Air Force officials told us that there are already thousands of differences between the aircraft the contractor is building and the specifications in the previous contract for five test aircraft. These test aircraft specifications are guiding the contractor's work. Air Force officials told us that it is important to have a mechanism to examine these differences. For example, DCMA officials identified over 8,000 differences between the test aircraft and the Air Force's contract specifications for those aircraft.
- A DCMA memo relating to APT production affirms that the contractor plans to build the forward and aft fuselages in facilities that will be building these critical components of the aircraft for the first time.
- According to program officials, the contractor has consistently failed to comply with the manufacturing standards in the indefinite delivery contract. This clause requires the contractor to comply with AS6500, which is a universal manufacturing management standard that requires production facilities to identify key and critical characteristics of the fabrication process and apply additional elements of quality

control to those elements.[20] Correspondence between DCMA and the contractor indicates that, since 2021, they have discussed what it means to be AS6500 compliant and have yet to fully agree. In 2022, the Air Force held an AS6500 summit with the contractor to better define what the Air Force was looking for from the contractor to establish AS6500 compliance. Air Force program officials told us they would have more confidence in the build quality of aircraft parts currently in production if the contractor met this standard. As of February 2023, the Air Force expects that the contractor will ask to remove this requirement from the terms of the contract.

Without a Contract, DCMA Cannot Oversee Production through Its Typical Processes

DCMA told us that, without a contract, it cannot oversee the production of an aircraft through its usual procedures. For the APT program, DCMA's primary role is to assure that the aircraft meets the contract specifications. In a letter to GAO, DCMA said it was concerned about violating various provisions of the law. DCMA also stated that, without a contract for purchase of the aircraft, there are no specifications and, therefore, there is nothing to compare to the aircraft, making oversight impossible.

Air Force officials said they approached DCMA about options for pre-contract oversight in the event that the contractor presents these aircraft for acceptance. However, DCMA officials informed the Air Force that they believe that conducting their typical oversight function for these aircraft is not possible for three reasons:

1. The aircraft production contract specification is not known, and enforcement of contract terms cannot be accomplished without a contract specifying those terms,

[20]Key characteristics are features that will have a significant impact on aircraft performance if they vary from the specifications. Critical characteristics are those that are likely, if defective, to cause hazards to human safety or result in the failure of a weapon system. Department of Defense, *Department of Defense Handbook: Manufacturing Management Program Guide,* MIL-HDBK 896A (August 25, 2016). AS6500 is a commercial standard governing the implementation of best practices for the management of manufacturing operations. Air Force officials said this includes identifying both key characteristics and critical characteristics associated with the risks of performance and safety issues.

2. DCMA does not have delegated authority or a funding mechanism for overseeing production of aircraft that are not on order,[21] and
3. Oversight could unwittingly commit the government to accept certain work even without a contract.[22]

Ultimately, the Air Force is responsible for making a decision to fully or partially accept or reject the aircraft the contractor delivers to satisfy the terms of the future contract. To do so responsibly, the Air Force and DCMA should have confidence that the aircraft align with the correct design and meet the contract specifications. Air Force and DCMA officials said that they have been in discussions about how to conduct oversight without a contract. However, they said that thus far, they have been unable to agree on a plan for effective oversight within the legal constraints previously noted. With limited oversight of production prior to ordering aircraft, the Air Force does not have a plan for determining the conditions by which it will accept production work completed prior to contract award.

Conclusions

The Air Force continues to rely on a decades-old system that is not analogous to modern fighter aircraft. The contractor's latest schedule, which is 10 years behind its initial estimates, continues to be optimistic, as it does not account for any additional development or testing problems. The Air Force conducted a risk assessment on the contractor's schedule but did not include the potential impact of two key risks—concurrency and contractor management. Without assessing these key risks, the program does not know the likelihood of meeting its current low-rate initial production targets. This could inhibit the Air Force's ability to plan for the sustainment of its current trainers and raise the costs of the APT aircraft.

Further, the contractor has begun production work without a contract from the Air Force for the aircraft. Thus, the contractor is using the old design for the five test aircraft to do production work, which it could present to the Air Force to satisfy future contract orders. However, with years of testing forthcoming, there will likely be issues and changes to the aircraft's design. As a result, the contractor's decision complicates the Air Force's

[21]DCMA officials said they do not have appropriations available to support oversight in advance of a contract and therefore could violate the Anti-Deficiency Act. Under the act, agencies may not spend, or commit themselves to spend, in advance of or in excess of appropriations. 31 U.S.C. § 1341.

[22]DCMA officials highlighted the risk of an implied contract. An implied-in-fact contract arises not from an explicit agreement, but is inferred based on the parties' conduct.

oversight of aircraft production. In the absence of a contract for the aircraft, the Air Force and DCMA have been unable to establish how to conduct oversight. Without a plan, the Air Force is at risk of not having the information it needs for determining the conditions under which it would accept production work completed prior to contact delivery.

Recommendations for Executive Action

We are making two recommendations to the Air Force.

The Secretary of the Air Force should ensure that the APT program conduct a schedule risk assessment that includes (1) risks associated with the overlap of development, testing, and production phases of the program, and (2) risks related to contractor management. (Recommendation 1)

The Secretary of the Air Force should make a plan for determining under what conditions it would accept production work completed prior to contract delivery. (Recommendation 2)

Agency Comments

We provided a draft of this report to DOD for review and comment. DOD concurred with our recommendations and did not provide a formal written response. DOD also provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committee, the Secretary of Defense, the Secretary of the Air Force, the Director of the Defense Contract Management Agency, and other interested parties. In addition, the report is available at no charge on the GAO website at http://www.gao.gov.

If you or your staff have any questions concerning this report, please contact me at (202) 512-4841 or ludwigsonj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are listed in appendix II.

Jon Ludwigson
Director, Contracting and National Security Acquisitions

Appendix I: Objectives, Scope, and Methodology

A House report related to a bill for the National Defense Authorization Act for Fiscal Year 2022 included a provision for us to examine cost, schedule, and performance for the Advanced Pilot Training (APT) program. We examined (1) what development challenges, if any, the APT program is facing; (2) the APT program's cost and schedule targets as well as any risk associated with meeting those targets, and (3) manufacturing plans for the APT aircraft.

To assess technology challenges the APT program is facing, we reviewed Air Force documentation of risks and problems associated with key technologies, and compared them to program requirements and schedule dependencies. We also reviewed documentation of test results from, for example, the escape system and early flight-testing. We met with program and test officials, as well as representatives from the contractor, to discuss these challenges and plans to address them. We also observed monthly program discussions with key stakeholders, which focused on these challenges.

To assess the APT program's schedule targets, we compared the program's recently updated schedule to initial baseline estimates. We also met with program officials to understand their process for developing the program schedule and identifying activities that are critical to timely execution of the schedule. To assess the extent to which the schedule is realistic, we examined the program's assumptions underlying its schedule risk assessment and compared those assumptions to program test schedules, technical problems and likely time frames from resolving them, and other program data. We also identified relevant schedule best practices from GAO's Schedule Assessment Guide.[1] We reviewed program documentation, in light of schedule delays and technical challenges, to understand the potential affect further delays might have on program costs beyond established contract costs.

To assess the Air Forces plans for manufacturing the APT, we reviewed documentation articulating plans for low-rate production, including correspondence between the contractor and the Air Force. We also reviewed roles and responsibilities of Defense Contract Management Agency (DCMA) contract administration officials, as well as documents outlining the potential courses of action those officials proposed relating to oversight of production. We met with Air Force and DCMA officials, and

[1]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: December 2015).

representatives from the contractor to identify each organization's constraints, motivations, and risks relating to oversight of APT production.

We conducted this performance audit from August 2022 to May 2023 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Jon Ludwigson, (202) 512-4841 or ludwigsonj@gao.gov

Staff Acknowledgments

In addition to the contact named above, the following staff members made key contributions to this report: Laurier Fish (Assistant Director), Andrew H. Redd (Analyst-in-Charge), Pete Anderson, Patricia Broadbent, Dev M. Chojar, Susan C. Ditto, Kurt Gurka, Tonya Humiston, and Sylvia Schatz.

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