



Report to the Subcommittee on  
Seapower and Projection Forces,  
Committee on Armed Services, House  
of Representatives

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June 2019

# KC-46 TANKER MODERNIZATION

Aircraft Delivery Has  
Begun, but  
Deficiencies Could  
Affect Operations and  
Will Take Time to  
Correct

Accessible Version

# GAO Highlights

Highlights of [GAO-19-480](#), a report to the Subcommittee on Seapower and Projection Forces, Committee on Armed Services, House of Representatives

## Why GAO Did This Study

Aerial refueling—the transfer of fuel from airborne tankers to combat and airlift forces—is critical to the U.S. military's ability to effectively operate globally. The Air Force initiated the KC-46 program in 2011 to replace about a third of its aging KC-135 aerial refueling fleet. Boeing was awarded a fixed-price incentive contract to develop the first four aircraft, which are being used for testing. Boeing was also required to deliver the first 18 fully capable aircraft by August 2017. The program plans to eventually field 179 aircraft.

This report assesses the program's progress toward meeting cost, schedule, and performance goals. The report also assesses how the program's contracting and sustainment planning approach could inform other acquisition programs.

GAO analyzed cost, schedule, performance, test, manufacturing, contracting, and sustainment planning documents; and interviewed officials from the KC-46 program office, other defense offices, such as the Defense Contract Management Agency, the Federal Aviation Administration, and Boeing.

## What GAO Recommends

GAO recommends that the Department of Defense disseminate insights in this report about the KC-46's contracting and sustainment planning experiences for consideration by acquisition programs, particularly those that plan to use a fixed-price-type development contract or a commercial derivative aircraft. The Department of Defense concurred with the recommendation.

View [GAO-19-480](#). For more information, contact Jon Ludwigson at (202) 512-4841 or [Ludwigsonj@gao.gov](mailto:Ludwigsonj@gao.gov).

June 2019

## KC-46 TANKER MODERNIZATION

### Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct

## What GAO Found

Costs for the KC-46 program remain lower than expected, as shown below.

**Initial and Current Acquisition Cost Estimates for the KC-46 Tanker Aircraft (then-year dollars in millions)**

	February 2011	January 2019	Percent Change
Development	7,149.6	5,857.7	-18
Procurement	40,236.0	34,188.7	-15
Military construction	4,314.6	2,872.1	-33.4
<b>Total</b>	<b>51,700.2</b>	<b>42,918.5</b>	<b>-17</b>

Source: GAO presentation of Air Force Data. | GAO-19-480

The Air Force accepted the first KC-46 in January 2019, but Boeing remains nearly 3 years behind schedule. As shown below, Boeing now plans to deliver the first 18 aircraft with all three aerial refueling subsystems by June 2020.

**Original and Current Program Schedule**

	2016	2017	2018	2019	2020
Original 2011 schedule	✈	★			
Current schedule				✈	★

✈ Delivery of the first aircraft      ★ Delivery of 18 aircraft with all aerial refueling systems

Source: GAO analysis of KC-46 program data. | GAO-19-480

**Data table for Original and Current Program Schedule**

	Delivery of the first aircraft	Delivery of 18 aircraft with all aerial refueling systems
<b>Original 2011 schedule</b>	February 2016	August 2017
<b>Current schedule</b>	January 2019	Jun 2020

Program officials expect the KC-46 to meet key performance goals over the next few years as it accumulates 50,000 fleet hours. However, the Air Force is accepting aircraft that do not fully meet contract specifications and have critical deficiencies, including ones that affect (1) the operators' ability to guide the fuel delivery boom into position, and (2) the boom itself. The deficiencies could affect operations and cause damage to stealth aircraft being refueled, making them visible to radar. Program officials estimate it will take 3 to 4 years to develop fixes for the deficiencies and a few more years to retrofit up to 106 aircraft. The Air Force and Boeing will incur costs to fix the deficiencies, with the Air Force's portion estimated to be more than \$300 million. The Air Force is withholding 20 percent payment on each aircraft until Boeing fixes the deficiencies and non-compliances. Meanwhile, the Air Force has limited some refueling operations.

GAO identified a number of insights that could benefit other programs, including the use of a fixed-price-type development contract and a correction of deficiencies clause in the contract that protected the government from some cost increases. The Department of Defense agreed to provide lessons learned about the KC-46 program for future acquisition programs based on a recommendation GAO made in March 2012, but does not plan to do so until development is complete in 2021. GAO believes other programs could benefit from insights identified in this report if they were disseminated sooner.

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June 12, 2019

The Honorable Joe Courtney  
Chairman  
The Honorable Robert Wittman  
Ranking Member  
Subcommittee on Seapower and Projection Forces  
Committee on Armed Services  
House of Representatives

The KC-46 aerial refueling tanker modernization program, currently valued at about \$43 billion, is one of the Air Force's highest acquisition priorities and will provide aerial refueling to Air Force, Navy, Marine Corps, and allied aircraft. The Air Force contracted with Boeing in 2011 to develop, test, and provide initial delivery of 18 KC-46 tankers by August 2017. The program recently completed its eighth year of a 9-year development program to modify the design of an aircraft originally designed for commercial use into an aerial refueling tanker. Aerial refueling—the transfer of fuel from airborne tankers to combat and airlift forces—is critical to the U.S. military's ability to effectively operate globally. The program eventually plans to field 179 KC-46 aircraft. These aircraft are intended to replace roughly one-third of the Air Force's aging aerial refueling tanker fleet, comprised mostly of KC-135 Stratotankers. As we have previously reported, Boeing has experienced problems wiring the aircraft and other issues that have caused program delays.<sup>1</sup>

You requested that we monitor the KC-46 program because of problems Boeing is experiencing in developing the aircraft. This report assesses the program's progress toward (1) meeting cost estimates and schedule goals; (2) achieving performance goals; and (3) completing testing. We also assessed how the program's contracting and sustainment planning approach could inform other acquisition programs that are considering a fixed-price-type development contract or using commercial derivative aircraft. This is our eighth report on the KC-46 program. See the related GAO Products page for a list of our previous KC-46 reports.

As part of our overall review, we reviewed key cost, schedule, performance, test, manufacturing, and sustainment documents to

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<sup>1</sup>GAO, *KC-46 Tanker Modernization: Program Cost is Stable, but Schedule May Be Further Delayed*, [GAO-18-353](#) (Washington, D.C.: Apr. 18, 2018).

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determine the status of the KC-46 program in 2018 compared to the initial plans. We interviewed officials from the Air Force's KC-46 program office, the Air Mobility Command, other defense offices, the Federal Aviation Administration, and Boeing to obtain more details and discuss our observations on the progress made in 2018. We also attended monthly meetings between the program office and Boeing, and visited two Boeing production facilities in Everett, Washington.

To assess progress toward achieving cost estimates, we compared current cost estimates to those established at the start of development and to estimates contained in our April 2018 report. To assess progress toward achieving schedule goals, we compared current schedule estimates to those established at the start of development and to estimates from our April 2018 report. For cost and schedule data, we reviewed program documents such as defense acquisition executive summary reports, selected acquisition reports, integrated master schedules, and program briefings.

To assess progress toward achieving performance goals, we compared key performance parameters for the KC-46 to their current status contained in program documents. We tracked the program's top critical deficiencies as reported in program briefing slides, and compared the deficiencies to what was required in the KC-46 development contract. To assess Boeing's progress toward completing testing, we compared planned and actual developmental flight test data and identified remaining program test activities, such as receiver aircraft certification testing and operational testing. We assessed the reliability of the cost, schedule, and test data by corroborating it using multiple sources including official reports or publications where possible, and by interviewing agency officials knowledgeable about the data. We determined that the data were sufficiently reliable for the purposes of reporting on the current status of the KC-46 program.

To report on how the program's contracting and sustainment approach could inform other acquisition programs considering a fixed-price-type development contract or commercial derivative aircraft, we analyzed the original KC-46 contract, contract modifications, and key sustainment documents. We compared the KC-46 program's contracting approach to the Federal Acquisition Regulation, Department of Defense guidance, and best practices we identified for capturing design and manufacturing knowledge on weapon acquisition programs. We reviewed a study that identified the benefits of maintaining Federal Aviation Administration certification for the KC-46 for sustainment purposes, and discussed key



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assumptions that have changed since the study was completed with program officials. We interviewed officials from the Air Force tanker directorate; KC-46 program office; Office of the Deputy Assistant Secretary of Defense for Systems Engineering; Under Secretary of Defense for Acquisition and Sustainment Defense Pricing and Contracting Office; Office of the Secretary of Defense Director, Operational Test and Evaluation; Deputy Assistant Secretary of Defense for Developmental Test and Evaluation; Defense Contract Management Agency; and the Federal Aviation Administration. We also interviewed representatives from Boeing.

We conducted this performance audit from July 2018 to June 2019 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.

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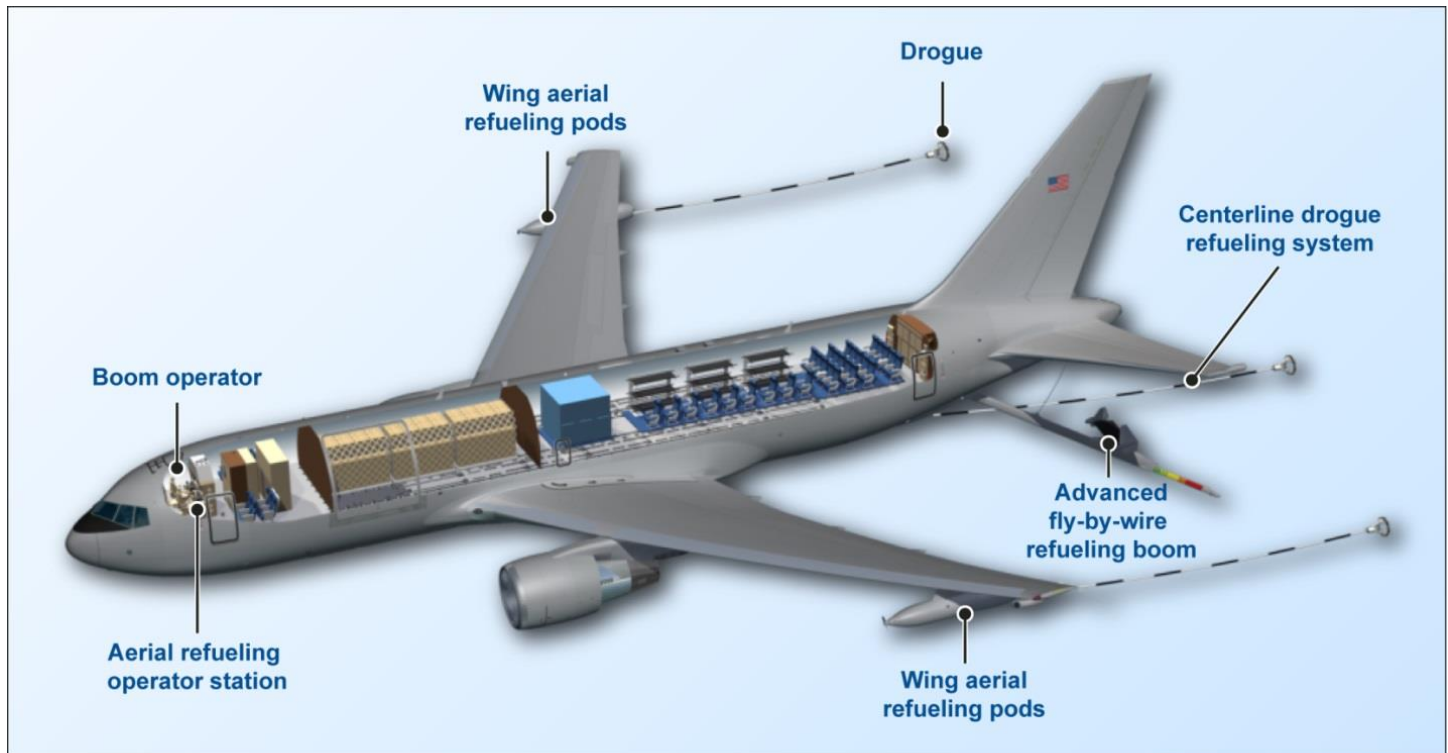
## Background

In February 2011, Boeing won the competition to develop the Air Force's next generation aerial refueling tanker aircraft, the KC-46. The KC-46 is to be equipped with subsystems that allow for two types of refueling—(1) a refueling boom that is integrated with a computer-assisted control system, and (2) a permanent hose and drogue refueling system. This dual refueling capability is an enhancement over prior tanker aircraft because it enables the KC-46 to use boom refueling for Air Force aircraft and drogue refueling for Navy or allied aircraft on a single flight. The majority of legacy tankers, such as the KC-135s, were configured for only one of these types of refueling and had to land and be reconfigured to use the other refueling system.

During boom refueling, an operator on the KC-46 tanker aircraft extends the boom—a rigid, telescoping tube—and inserts it into a receptacle on the aircraft being refueled. The KC-46 also has a remote vision system, which consists of a display, cameras, and computer processors, in lieu of a window that legacy tankers use. The system allows operators to observe the position of the boom and the receiving aircraft, and to reposition the fuel delivery system to facilitate refueling. In contrast, during drogue refueling, an operator uses the hose and drogue system—comprised of a long, flexible refueling hose and a parachute-like metal

basket that provides stability—to provide fuel to receiver aircraft. Drogue refueling is available via the centerline drogue system in the middle of the tanker aircraft or via wing aerial refueling pods located on each wing. While refueling with the drogue or wing aerial refueling pods, the operator uses the remote vision system to identify when to extend or reel in the hoses. The wing aerial refueling pods can be used for simultaneous refueling of two Navy or allied aircraft—an enhanced capability that only 20 of the 414 KC-135 tankers currently have the capability to do. Figure 1 shows the boom and drogue refueling subsystems on the KC-46.

**Figure 1: KC-46 Refueling Subsystems**



Source: GAO representation of ©2014 Boeing image. | GAO-19-480

Note: The figure depicts a KC-46 with a configuration for cargo, passengers, and aeromedical evacuation, but the aircraft can also be configured in a variety of different ways.

The KC-46 tanker is a commercial derivative aircraft that is based on Boeing's commercial 767 aircraft. To convert a 767 to a KC-46 tanker, Boeing modified the aircraft design in two phases. In the first phase, Boeing changed the design of the 767 to include a cargo door, new fuel tanks, and an advanced flight deck display borrowed from the 787 aircraft. This baseline non-military aircraft is called the 767-2C and is

being built on Boeing's existing 767 production line. In the second phase, Boeing added military systems to the 767-2C and brought it to a KC-46 configuration in a separate Boeing modification facility. The completed KC-46 aircraft are then taken to a test and delivery center for Air Force acceptance.

By using a commercial derivative aircraft, the Air Force intended to avoid the long process and costs associated with designing, testing, and evaluating a new aircraft. It also wanted to reap the benefits of decades of reliability upgrades Boeing made to the aircraft for commercial customers, an established commercial infrastructure for spare parts, and maintenance and training data needed for sustainment that have been validated and verified by the commercial industry, among other things.

According to an Air Force Policy Directive in place at the time of contract award, programs that are based on commercial derivative aircraft are required to achieve Federal Aviation Administration certification to the maximum extent practical.<sup>2</sup> The Air Force went further and required the contractor to exhaust all possible solutions to obtain Federal Aviation Administration certification on both commercial and military-unique parts—including the boom, centerline drogue system, and wing aerial refueling pods—before seeking military certification.

The Federal Aviation Administration previously certified the airworthiness of Boeing's 767 commercial passenger airplane (referred to as a type certification), and in December 2017, awarded the amended type certificate for the 767-2C aircraft to Boeing. The amended type certificate allowed Boeing to use the 767-2C aircraft as the baseline non-military aircraft for the KC-46. Then, in September 2018, the Federal Aviation Administration certified the design of the KC-46 with a supplemental type certificate. The supplemental type certificate signifies the Federal Aviation Administration's approval of the KC-46's airworthiness, including mission systems such as its aerial refueling components. According to program officials, the Air Force granted a limited duration airworthiness certification for the KC-46 in November 2018 to support the initial fielding, which they said is common for new aircraft. The Air Force is continuing testing to obtain a military type certification from the Air Force Engineering Directorate, expected in several years. See figure 2 for a depiction of the

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<sup>2</sup>Air Force Policy Directive 62-6, *USAF Airworthiness* (June 11, 2010), superseded by Air Force Policy Directive 62-6, *USAF Airworthiness* (Jan. 16, 2019).

conversion of the 767 aircraft into the KC-46 tanker with the boom deployed and the Federal Aviation Administration's airworthiness certificate needed at each stage.

**Figure 2: Certifications Needed for Conversion of Boeing 767 into KC-46 Aerial Refueling Tanker**



Source: GAO analysis of Boeing data (data); © Boeing (images). | GAO-19-480

During development, Boeing is expected to prove the aircraft's design and demonstrate that the aircraft performs as expected. This type of testing is referred to as developmental testing. This testing was originally planned to occur within a 15-month window starting in early 2015 and ending in 2016.

Initial operational test and evaluation—expected to occur after developmental testing and referred to in our report as operational testing—is conducted on production aircraft, or production representative articles. During this testing, the Air Force determines whether systems are operationally effective and suitable to support a full-rate production decision. The Air Force obtained a military flight release in November 2018, which allows it to start operational testing. To support operational testing, the Air Force is undertaking testing to certify the KC-46 to refuel various receiver aircraft, such as the F-15 fighter and B-52 bomber. After the first four KC-46 aircraft are delivered and two receiver aircraft are certified for refueling, the Air Force will begin operational testing.

The Air Force awarded Boeing a fixed-price incentive (firm target) contract to develop the KC-46, which includes the design, manufacture, and delivery of four test aircraft.<sup>3</sup> Barring any changes, the contract specifies a ceiling price of \$4.9 billion for Boeing to develop the first four aircraft. Once that price was reached, Boeing would assume responsibility for all additional costs for developing those aircraft. The Air Force used a fixed-price incentive development contract because KC-46 development was considered to be a relatively low-risk effort to integrate mostly mature military technologies onto an aircraft designed for commercial use. The contract limits the government's financial liability and provides the contractor incentives to reduce costs to earn more profit. The contract specifies a 60/40 incentive ratio for sharing savings in the event of underruns, or sharing costs in the event of overruns in relation to the target cost. The government's share is 60 percent, while Boeing's is 40 percent. Cost sharing ends when the contract price reaches the \$4.9 billion ceiling. Thereafter, Boeing is responsible for all additional costs associated with the overruns. The contract also specifies that Boeing must correct any deficiencies and bring development and production aircraft to the final configuration at no additional cost to the government.

In addition, the contract includes options for Boeing to manufacture 175 aircraft with firm-fixed-price contract options for the first two production lots, and options with not-to-exceed fixed prices for production lots 3 through 13. For purposes of this report, a production lot refers to a set number of aircraft that must be built and delivered in a given time frame and procured with a specific year of budget funding. The original contract required Boeing to deliver 18 operational aircraft, nine sets of wing aerial refueling pods, and two spare engines by August 2017.

The Under Secretary of Defense for Acquisition, Technology and Logistics approved the KC-46 program to enter low-rate initial production

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<sup>3</sup>This contract type specifies a target cost, a target profit, a price ceiling and a profit adjustment formula (also known as a share-line or incentive ratio). The price ceiling is the maximum that may be paid to the contractor, except for any adjustment under other contract clauses. When the final cost is less than the target cost, application of the incentive ratio results in a final profit greater than the target profit; when final cost is more than target cost, the final profit is less than the target profit. If the final costs exceed the price ceiling, the contractor absorbs the difference.

in August 2016.<sup>4</sup> Originally, the Air Force planned for the first two production lots to be low-rate production lots. The 19 aircraft associated with these two lots, or 11 percent of the 175 production aircraft, were to be built concurrent with developmental flight testing. The Office of the Under Secretary of Defense for Acquisition, Technology and Logistics approved additional low-rate production lots—lots three through five—in 2016 and 2017 to avoid interrupting the planned production of additional aircraft. As we have reported over the past several years, Boeing had problems developing the aircraft, which resulted in schedule delays and a decision by Boeing and the program office to separate the delivery of the first 18 aircraft from the delivery of the first nine sets of wing aerial refueling pods.<sup>5</sup>



As of March 2019, the Air Force has exercised options for the first four low-rate production lots, for 52 aircraft totaling about \$7.8 billion. As a result, the number of aircraft being produced concurrent with developmental flight testing has increased to 52 aircraft, or 30 percent of the total number Air Force expects to purchase. Traditionally, the Department of Defense tracks concurrency to determine financial risk to the federal government; however, in this case, due to the terms of the development contract, the government's liability was limited to sharing in cost overruns only up to the contract's ceiling price. Figure 3 shows the number of aircraft the Air Force plans to procure in each lot.

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<sup>4</sup>The Office of the Undersecretary of Defense for Acquisition, Technology and Logistics was reorganized effective February 1, 2018. There is now an Undersecretary of Defense for Acquisition and Sustainment who advises the Secretary on all matters regarding acquisition and sustainment and will be involved in the oversight of individual programs as required.

<sup>5</sup>[GAO-18-353](#) and *KC-46 Tanker Modernization: Delivery of First Fully Capable Aircraft Has Been Delayed over One Year and Additional Delays are Possible*, [GAO-17-370](#) (Washington, D.C.: Mar. 24, 2017).

Figure 3: Planned KC-46 Procurement of 175 Production Aircraft

	Option exercised (purchased)				Planned (targeted buys )									
 Procurement lot	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9	Lot 10	Lot 11	Lot 12	Lot 13	= Total lots 13
 Number of aircraft per lot	7	12	15	18	15	12	15	12	12	15	15	15	12	= Total aircraft 175

Source: GAO analysis of KC-46 program data. | GAO-19-480

Note: Procurement lots 7-13 represent targeted buys. The Air Force has the flexibility to adjust the number of aircraft in each of these lots.

## Current Cost Estimate Is Less than Original Estimate, but Program Remains Years behind Schedule and Will Need to Address Deficiencies

The KC-46 program's cost estimates have remained lower than initially estimated, consistent with our past reports.<sup>6</sup> The KC-46 program's total acquisition cost estimate is currently about \$43 billion, or about \$9 billion lower than the original 2011 estimate. The Air Force was able to decrease its cost estimate in large part because funds set aside for potential design changes were not needed. After a 3-year delay from the original plan, the Air Force began conditionally accepting the first seven KC-46 aircraft in early 2019.

### Total Government Cost Estimate Has Declined Since the Initial Estimate

The KC-46 program's total acquisition cost estimate remains lower than the initial estimate, consistent with our April 2018 report. As of January 2019, the Air Force estimates that the total program acquisition cost for the KC-46, which includes development, procurement, and military construction costs, will be about \$43 billion. This is about \$9 billion, or 17 percent, less than the original estimate of \$51.7 billion made in 2011.

<sup>6</sup>GAO-18-353 and GAO-17-370.

Correspondingly, the average acquisition cost of each aircraft has also decreased by 17 percent because aircraft quantities have remained the same. Table 1 provides a comparison of the initial and current quantity and cost estimates. The estimates include, among other things, the expected costs of the development and procurement contracts awarded to Boeing, government test and evaluation costs, program office expenses for advisory and assistance services from support contractors, as well as contingency funding that might be needed to address the potential risk of requirements changes or other unexpected issues.

**Table 1: Initial and Current KC-46 Tanker Aircraft Program Quantities and Acquisition Cost Estimates**

		Initial Estimate (February 2011)	Current Estimate (January 2019)	Change (percent)	Difference
Expected quantities	Development quantities	4	4	—	0.0
	Procurement quantities	175	175	—	0.0
	Total quantities	179	179	—	0.0
Acquisition cost estimates (then-year dollars in millions)	Development	7,149.6	5,857.7	-18.0	1,291.9
	Procurement	40,236.0	34,188.7	-15.0	6,047.3
	Military Construction	4,314.6	2,872.1	-33.4	1,442.5
	Total program acquisition	51,700.2	42,918.5	-17.0	8,781.7
Per Aircraft cost estimates (then-year dollars in millions)	Average acquisition cost	288.8	239.8	-17.0	49

Source: GAO analysis of KC-46 program. | GAO-19-480

Note: Then-year dollars include the effects of inflation and price changes.

Overall, the Air Force decreased its development and procurement cost estimates by about \$1.3 billion and \$6 billion, respectively. As we have previously reported, the main reason for the decrease is it has not needed the large amount of contingency money the Air Force included in the initial estimates for possible requirements changes.<sup>7</sup> Military construction cost estimates also decreased by about \$1.4 billion as the Air Force decided, for example, to reuse existing facilities at its operating bases rather than build new ones.

<sup>7</sup>[GAO-18-353](#).



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In contrast, as of February 2019, Boeing representatives estimate that costs to complete development have increased to about \$6.2 billion, or about \$1.3 billion over the contract ceiling price of \$4.9 billion, due to development problems. Specifically, Boeing experienced problems related to wiring the aircraft, design issues with the fuel system components, a fuel contamination event that corroded the fuel tanks of one of the development aircraft, and test delays. According to the fixed-price incentive contract, the government is generally not responsible for these additional costs to the extent they exceeded the ceiling price of the development contract.

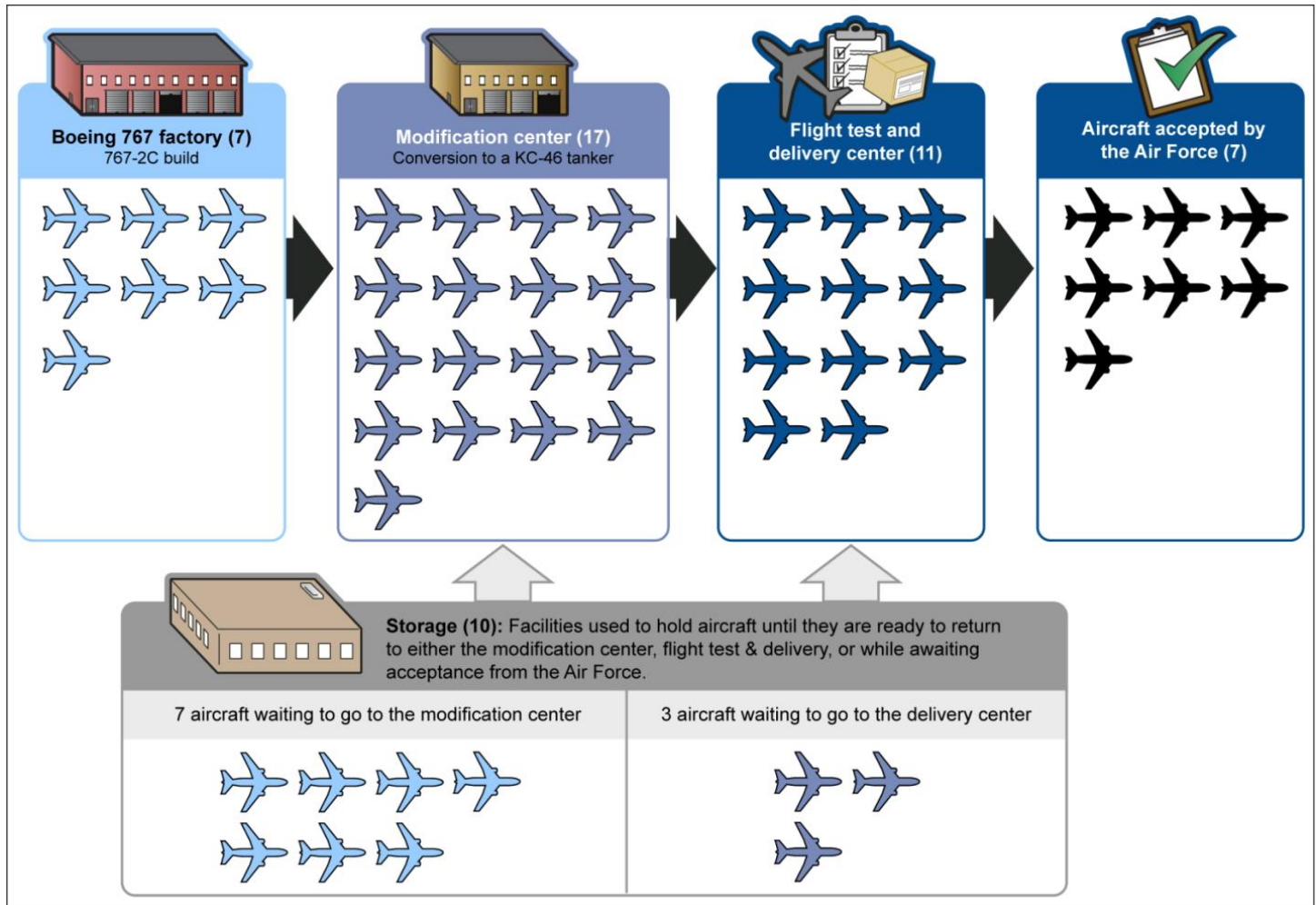
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### Air Force Began Accepting Aircraft in January 2019 with Several Critical Deficiencies That Will Need to Be Addressed

The Air Force conditionally accepted the first seven KC-46 production aircraft between January and March 2019, about 3 years later than originally planned, with three critical deficiencies related to the refueling subsystems. Although the federal government generally has no obligation to accept work that does not meet contract requirements, program officials told us that the Air Force negotiated minimum specifications under which it would begin conditionally accepting aircraft. Officials told us that among other benefits, conditionally accepting these aircraft provides the Air Force additional military capability and the aircraft can be used to start operational testing. These aircraft are among the 18 aircraft required by the original contract.

As of April 2019, Boeing was producing the remaining 45 additional aircraft associated with the first four low-rate initial production lots. Some of the aircraft just started production on Boeing's 767 production line. Others are further along and being modified to become KC-46 aircraft in a separate facility, or are being tested and taken to the delivery center for Air Force acceptance. Still others are in storage, either waiting to be transferred to the KC-46 modification center to be retrofitted with the latest wiring configuration or transferred to the delivery center to prepare for Air Force acceptance. Figure 4 shows where these 45 aircraft are in Boeing's production and delivery process, along with the seven aircraft already delivered.

Figure 4: Aircraft in the Boeing KC-46 Production Process (As of April 2019)

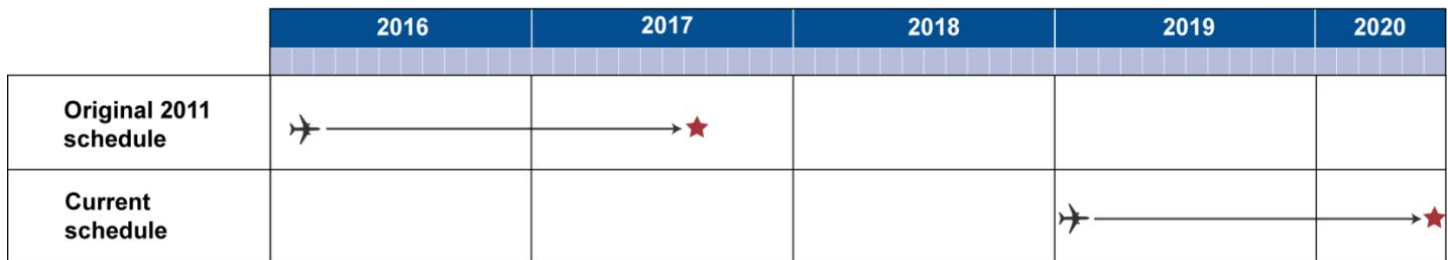


Source: GAO analysis of KC-46 program data. | GAO-19-480

Boeing is not expected to meet its most significant delivery requirement so far until mid-2020, 34 months after originally planned and almost 20 months later than we found in April 2018. Specifically, program officials anticipate that the Air Force will accept the first 18 aircraft by August 2019, and nine sets of wing aerial refueling pods by June 2020—which together with two spare engines constitute the contractual delivery requirement contained in the development contract. According to program officials, Boeing continued to have difficulty providing design documentation needed to start Federal Aviation Administration testing for the wing aerial refueling pods over the past year, which caused the additional delays beyond what we reported last year. Figure 5 shows the

original and current delivery schedules for completing the development contract requirement.

**Figure 5: Comparison of Original and Current Program Schedules for Delivery of the First 18 Aircraft and All Refueling Systems**



✈️ Delivery of the first aircraft

★ Delivery of 18 aircraft with all aerial refueling systems

Source: GAO analysis of KC-46 program data. | GAO-19-480

In February 2019, the Air Force stopped accepting KC-46 aircraft from Boeing because it had identified foreign object debris, including tools, in aircraft it had already accepted, as well as in the aircraft that were in the final stages of acceptance. Boeing issued a corrective action plan outlining steps the company needed to take to improve its foreign object debris identification and prevention activities before the Air Force would accept additional aircraft. Some of the steps included conducting daily inspections of each aircraft for foreign object debris, having Boeing production personnel submit lost tool reports to their superiors, and developing strategies for containing the debris issue, such as only taking the exact amount of small parts needed for an individual job in the aircraft build. The Air Force began accepting aircraft again after Boeing took steps to address the problem.

However, in March 2019, Boeing found additional foreign object debris as it was conducting its newly implemented daily inspections and the Air Force suspended deliveries again. Boeing implemented additional corrective actions to the Air Force's satisfaction and, as of April 2019, the Air Force has authorized the resumption of KC-46 deliveries. Program officials stated that Boeing is responsible for the costs to inspect and remove foreign object debris from aircraft that have already been accepted and that are in various stages of the Boeing manufacturing process.

Because of the delivery delays to date and other factors in the existing tanker fleet, an Air Mobility Command official said leadership is currently planning to fly and maintain some legacy KC-135 tankers longer than

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planned until the KC-46 is available to conduct missions. According to the official, the Air Force plans to reallocate \$57 million in fiscal year 2020 funds from the KC-46 program to the KC-135 program to support this decision. The funding would cover the cost to fly and sustain some KC-135 aircraft above what the Command had planned, including the associated personnel costs. Air Mobility Command officials said that decisions about retaining some legacy KC-135 aircraft will be reviewed annually thereafter. If these aircraft are retained, funding would be reallocated from the KC-46 program to support the decision.

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## Program Expects All Performance Goals Will Be Met, but Correcting Critical Deficiencies Will Take Several Years at a Cost to Boeing and the Government and Could Affect Operations

The program continues to expect that the KC-46 aircraft will ultimately meet its high-level system performance goals, such as those related to aerial refueling and operational availability. However, the Air Force and Boeing expect that the critical deficiencies that could affect the aircraft's aerial refueling operations will take several years to address at a cost to both the government and Boeing.

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## Program Expects KC-46 Aircraft Will Meet Key Performance Goals

Program officials reported that, similar to what we reported last year, they expect the KC-46 will ultimately meet all of its 21 performance goals. These goals include nine key performance parameters and five key system attributes set by the Air Force, as well as seven technical performance measures Boeing established to track its own progress toward meeting contract specifications.<sup>8</sup> Appendix I provides a description of each of the performance goals.

According to Air Force test officials, the program plans to ascertain if the aircraft meets its 14 key performance parameters and key system

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<sup>8</sup>A key system attribute is an attribute that is considered important but not critical to meeting a system goal. A key performance parameter is considered critical to the development of an effective military capability.

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attributes during the operational test period, which began in May 2019. For example, the Air Force will test the tanker's ability to effectively refuel receiver aircraft with boom and drogue refueling on the same mission. The Air Force will also collect data to assess the operational availability of the aircraft. Operational availability is defined as the percentage of time the aircraft is available to complete its mission, which includes refueling aircraft or transporting cargo or people, when needed. The KC-46 needs to be available at least 80 percent of the time. Air Mobility Command officials will continue to monitor operational availability of the aircraft after it has been fielded to inform maintenance and future upgrade decisions.

An important key system attribute is reliability and maintainability, which has implications on aircraft availability and life cycle costs. In general, aircraft that are reliable and easy to maintain are typically available more often to perform missions and can experience lower life cycle costs. To help assess this key system attribute, the Air Force set a reliability growth goal that is based on the mean time between unscheduled maintenance events due to equipment failure. This is defined as the total flight hours divided by the total number of incidents requiring unscheduled maintenance. The goal is 2.83 flight hours between unscheduled maintenance events due to equipment failure by the time the aircraft reaches 50,000 flight hours. As of February 2019, the program had completed 3,928 flight hours, achieving 2.51 hours at that time. Program officials believe that the reliability will improve as additional flight hours are completed and as unreliable parts are identified and replaced.

According to Boeing representatives, the company met or is projected to meet the seven technical performance measures it tracked during KC-46 development. For example, the aircraft is now below the target weight of 204,000 pounds. In addition, program officials said that the aircraft is within the range of gallons of fuel used per flight hour that is specified in the contract. Boeing also projects that the aircraft will meet other measures, such as Air Force maintainers being able to fix mechanical problems on the aircraft within 12 hours 71 percent of the time once the aircraft has accumulated 50,000 fleet hours of service.

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### Program Estimates It Will Take Several Years to Fix Critical Aerial Refueling Deficiencies at a Cost to Boeing and the Air Force

Boeing and the Air Force are working to resolve three critical deficiencies related to the performance of the aerial refueling systems that the Air

Force discovered during developmental testing. These deficiencies are related to contract specifications, which are at a greater level of specificity than the performance goals. The Air Force determined that the deficiencies in these systems could result in damage to some of the aircraft that are being refueled by the KC-46 and identified them as Category 1 urgent deficiencies that need to be addressed.<sup>9</sup> The Air Force expects that it will take 3 to 4 years for Boeing to develop design solutions for these issues and a few more years to retrofit existing aircraft. A description of the deficiencies and how they are being addressed are discussed below.

- **Remote Vision System Did Not Provide Visual Clarity in All Lighting Conditions:** During developmental flight testing, there were instances when the aerial refueling operator was not able to make contact with the receiver aircraft for refueling as intended. This was because the remote vision system camera and processor had difficulty making timely adjustments to some environmental conditions. According to Boeing and program officials, these conditions include certain sun angles, where the glare from the sun can cause the receiver aircraft to washout or blackout on the display screen, making it difficult for the aerial refueling operator to sufficiently see the receptacle of the receiver aircraft to start refueling. The remote vision system also does not provide sufficient depth perception to safely refuel in all lighting conditions.

Boeing has already made changes to the remote vision system software to improve visibility for refueling operators. According to program officials, the changes included adjusting the contrast on the display screen and increasing the speed at which operators can switch between different screen viewing options. However, these changes did not address the Air Force's concerns regarding whether the system could support refueling in all conditions as called for under the contract, which requires sufficient visual clarity in all lighting conditions.

Boeing has agreed to redesign the remote vision system to meet the requirement. According to program officials, Boeing has not yet developed a solution, but has reported the redesign will include additional software and hardware changes. Program officials estimate that it may take Boeing 3 to 4 years to develop a solution for the

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<sup>9</sup>Category 1 deficiencies do not have workarounds. Category 2 urgent deficiencies have workarounds, such as procedural restrictions.

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remote vision system and have it certified by the Federal Aviation Administration so that aircraft parts will continue to be certified to the greatest extent possible. It will then take a few more years after that to retrofit all aircraft that are operating without the new system at that time. Boeing did not provide a cost estimate for this solution, but will fix and retrofit all aircraft at no cost to the government. In the meantime, program officials said the Air Force has placed limitations on some boom refueling operations.

- **Lack of Remote Vision System Clarity Also Caused Undetected Contacts with Receiver Aircraft:** As we reported in April 2018, during developmental flight testing, there were instances where the boom nozzle contacted a receiver aircraft outside the refueling receptacle.<sup>10</sup> According to program officials, in many of these instances, the aerial refueling operators were unaware that those contacts had occurred. Boom nozzle contact outside the receptacle can damage antennae or other nearby structures. It is especially problematic for low-observable receiver aircraft, such as the F-22 fighter, because boom contact can also damage their special coatings and render them visible to radar.

Boeing and program officials now anticipate that any hardware or software changes Boeing makes to the remote vision system, as discussed above, will also address the issue of undetected contacts with receiver aircraft. Efforts to address this issue are expected to be made at no cost to the government.

- **Boom Stiffness Hampered KC-46 Refueling of Lighter Receiver Aircraft:** During developmental flight testing, pilots of lighter receiver aircraft, such as the A-10 and F-16, reported the need to use more power to move the boom forward while in contact with the boom to maintain refueling position. According to program officials, the KC-46 boom currently requires more force to compress it sufficiently to maintain refueling position than the boom on the KC-135 or the KC-10. In addition, program officials said that the additional force exerted by the lighter aircraft can also create an issue when the boom is disconnected. This is because the additional required power can cause the receiver aircraft to lunge forward into the boom and strike it, possibly damaging the receiver aircraft and the boom. The severity of the damage depends on the location of the refueling receptacle, which differs based on the aircraft type. In the case of the A-10, the receptacle is located on the nose of the aircraft and the boom stiffness creates a greater risk to the pilot because a boom strike could

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<sup>10</sup>[GAO-18-353](#).

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damage the windshield. For the F-16, the receptacle is located behind the cockpit and a boom strike could damage the vertical surfaces of its tail. The Air Force is currently allowing F-16s to be refueled by the KC-46 in operational test and training environments, but not the A-10 until the boom stiffness has been fixed.

Modifications to address the boom stiffness will add cost for the government. Program officials said the development contract did not specify the amount of force needed to compress the boom. As part of the KC-46 low-rate initial production decision, the Air Force concurred with Boeing's proposed specifications, which are built into the current boom. Therefore, program officials said the Air Force will be responsible for costs associated with designing a solution for the boom stiffness and retrofitting aircraft. They said the deficiency will require a hardware change. Program officials believe that it will likely take 3 to 4 years to develop a solution and get it certified by the Federal Aviation Administration. It will then take additional time to retrofit about 106 aircraft in lots 1 to 8. The total estimated cost for designing and retrofitting aircraft is more than \$300 million.

The Air Force has taken steps to keep Boeing incentivized to address the deficiencies in a timely manner. In particular, at the time the Air Force accepted each aircraft, the government had already made progress payments to Boeing comprising 80 percent of the estimated price for each aircraft. Air Force officials stated that the program is currently withholding the remaining 20 percent payment on each aircraft until Boeing meets all contract specifications and corrects critical deficiencies.

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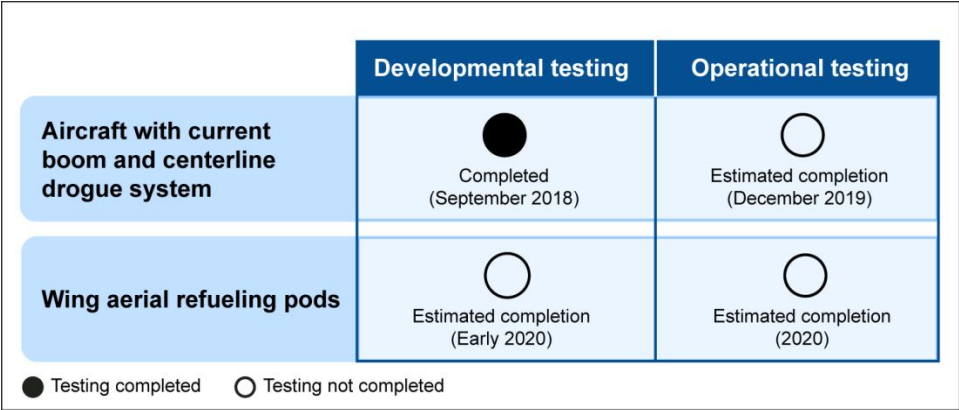
## Additional Test and Analysis Required to Validate That KC-46 Aircraft Fully Meet Key Contract and Mission Requirements

Over the next year, Boeing is to conduct developmental testing on the wing aerial refueling pods and correct deficiencies, and the Air Force is to finish analyzing test data to validate that performance and contract specifications have been met. In addition, the Air Force is to complete operational testing (planned for completion in December 2019) to determine if the KC-46 and its subsystems are fully capable of performing its mission in a realistic operational environment. Since our last report in April 2018, Boeing completed developmental testing and obtained airworthiness certification from the Federal Aviation Administration for the KC-46 aircraft and two of its three aerial refueling systems—the boom



and the centerline drogue system. This has allowed the Air Force to start accepting aircraft. Figure 6 shows the status of the KC-46 test activities.

**Figure 6: Completion Time Frames for KC-46 Test Activities as of March 2019**



Source: GAO analysis of KC-46 program data. | GAO-19-480

**Developmental Testing:** As of March 2019, Boeing had completed about 92 percent of the overall KC-46 developmental test program. The roughly 8 percent remaining, which consists of 2,303 of the 29,181 total developmental test points, relates to the wing aerial refueling pods. According to program officials, Boeing, in coordination with its supplier for this subsystem, submitted test plans to the Federal Aviation Administration in December 2018 for approval to begin flight testing the wing aerial refueling pods. These officials also told us that developmental testing on the pods began in early June 2019. Boeing projects that the Air Force will verify that the pods meet contract specifications and they will be airworthy by May 2020.

The Air Force is also currently reviewing developmental test data to validate that performance and contract specifications have been met and identify aircraft deficiencies. As of March 2019, the Air Force has identified the three critical deficiencies that we discussed earlier in this report. It also identified 160 Category 2 urgent deficiencies that Air Force policy notes can be addressed through workarounds, which can include manual updates or procedural restrictions. For example, the flight control system does not have an indicator that would alert the KC-46 operators that they are overriding the automatic system that keeps the boom aligned with the receiver aircraft. If the boom is not aligned with the receiver aircraft, it can cause damage to the boom and the receiver aircraft. Program officials said that, as a result, the Air Force has currently placed limitations on some boom refueling operations. The number of

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Category 2 urgent deficiencies went up by about 26 percent between mid-February and the end of March 2019. Program officials attributed this growth to the progress the Air Force is making in analyzing test data and validating whether the aircraft meet contract specifications. The Air Force may identify additional deficiencies as it completes these developmental testing activities and during operational testing.

Operational Testing: According to program officials, the Air Force Operational Test and Evaluation Center plans to conduct KC-46 operational testing from mid-May to December 2019. Operational testing is centered on five overarching test objectives.

- Three test objectives are focused on the ability of the KC-46 to perform operations for refueling, airlift, and aeromedical evacuation, including how quickly the KC-46 can offload fuel to a receiver aircraft.
- The fourth objective is focused on the ability of the KC-46 to meet its mission tasking, which includes measures such as the KC-46's availability and ability to complete a mission.
- The fifth objective addresses whether the KC-46 is logistically supportable through measures including aircrew and maintainer training, and how well the demand can be met with available parts.

According to Air Force test officials, operational testing consists of about 500 test conditions, each of which may include multiple test points. The Air Force plans to use four KC-46 aircraft for operational testing.

During operational testing for aerial refueling, the Air Force will test whether the KC-46 can deliver fuel through the boom or centerline drogue system to 18 different types of receiver aircraft in operational conditions, including refueling another KC-46. The Air Force needs to certify receiver aircraft for refueling before these aircraft can be used for operational testing with the KC-46. Boeing and the Air Force are in various stages of testing and certifying 18 receiver aircraft. In its 2018 annual report, the Department of Defense's Office of the Director, Operational Test and Evaluation reported that the duration of the KC-46 operational test period will depend on how long it takes the Air Force to certify all 18 receiver aircraft. As of March 2019, two aircraft have been tested and certified by the Air Force as a receiver to the KC-46. Five have completed testing, but have not yet been certified, and testing for two others has begun. Figure 7 shows the status of testing and certifications for the KC-46 receiver aircraft currently planned for operational testing. The Air Force plans to obtain additional certifications for aircraft that are not being used for operational testing.

**Figure 7: Status of the KC-46 Receiver Aircraft Testing and Certifications for Operational Testing as of March 2019**

Receiver aircraft		Testing status	Certification status
<b>Aircraft certified for boom refueling</b>			
1	F-16D fighter	●	●
2	C-17A transport	●	●
3	A-10 attack <sup>a</sup>	●	◐
4	B-52 bomber	●	◐
5	F-15E fighter	●	◐
6	KC-46 tanker <sup>b</sup>	●	◐
7	F-35A fighter	◐	○
8	EC-130H electronic attack	◐	○
9	B-2 bomber	○	○
10	F-22A fighter	○	○
11	B-1B bomber	○	○
12	C-5M transport	○	○
13	KC-10A tanker <sup>c</sup>	○	○
14	KC-135 R/T tanker	○	○
15	EC-130J military information	○	○
<b>Aircraft certified for centerline drogue refueling</b>			
1	F/A-18C/D fighter and attack	●	◐
2	F/A-18 E/F fighter and attack	○	○
3	CV-22 vertical lift transport	○	○
○ Not started    ◐ On-going    ● Completed			

Source: GAO analysis of Air Force and KC-46 program data. | GAO-19-480

<sup>a</sup>The A-10 completed testing as a receiver aircraft, but is not cleared to refuel with the KC-46 until the stiff boom has been fixed.

<sup>b</sup>The KC-46 completed testing as a tanker receiving fuel from another KC-46, but has not yet obtained certification. The KC-46, however, has completed testing and obtained certification to receive fuel from a KC-135R/T.

<sup>c</sup>The KC-10A will be tested and certified as a tanker refueling the KC-46 and as a receiver aircraft.

The Air Force schedule for completing receiver testing continues to shift. According to Department of Defense developmental and operational test officials and program officials, it is taking longer than expected to complete receiver aircraft certification testing in advance of operational testing due in part to receiver aircraft availability. According to these officials, Air Force major commands have been reluctant to allow their receiver aircraft to be tested with the KC-46 over concerns that the lack of

visual clarity in the remote vision system and the boom's stiffness could cause the boom to strike and damage the receiver aircraft. Program officials told us that, as a result, negotiations between the KC-46 program and Air Force major command officials concerning the use of receiver aircraft are taking longer than expected. These difficulties have resulted in delays to certification tests, in some cases for several weeks. The lack of availability of specific aircraft when they are scheduled to be tested may require the Air Force to reschedule other receiver aircraft. These schedule changes can require some resequencing of test planning and approval activities.

In addition, because the wing aerial refueling pods have not been certified and delivered, the Air Force will need to conduct operational testing on refueling operations for them later. To conduct this test, major commands with receiver aircraft that require drogue refueling would need to provide receiver aircraft again. According to program test officials, the start of operational testing for the wing aerial refueling pods will depend on whether the Air Force Operational Test and Evaluation Center uses pods that have not been certified for airworthiness by the Federal Aviation Administration or waits until Boeing delivers a certified subsystem. Problems requiring changes could be identified during KC-46 operational testing, developmental and operational testing for the wing aerial refueling pods, or receiver aircraft certification testing. The development contract makes Boeing responsible to correct any deficiencies discovered during these test periods that do not meet contract specifications.

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## KC-46 Program Offers Insights for Future Acquisition Programs on the Benefits and Challenges of a Fixed-Price-Type Development Contract and a New Sustainment Approach

Based on our own observations, as well as our discussions with Department of Defense officials who have been involved with the KC-46 program for many years, we identified aspects of its acquisition approach that could provide insights to future programs. Specifically, the insights could apply to programs considering a fixed-price development contract and determining what sustainment approach to use for commercial derivative aircraft. For example, the KC-46 development contract provided some financial protection to the government from increases in development and some life cycle costs. However, other aspects of the

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contract did not require Boeing to demonstrate high levels of aircraft performance prior to being awarded production contracts or receiving payment for its work. Current and former program officials also provided insights about key aspects of program management that they believe are essential for executing fixed-price development contracts based on their experiences. In addition, the Air Force's new approach for sustaining the KC-46, relying heavily on the Federal Aviation Administration to certify even military-unique aircraft systems, could be useful in considering future acquisition approaches.

We previously recommended in March 2012 that the Under Secretary of Defense for Acquisition, Technology and Logistics closely monitor the cost, schedule, and performance outcomes of the KC-46 program to identify positive or negative lessons learned for future acquisition programs.<sup>11</sup> We noted that, as one of only a few major acquisition programs to award a fixed-price incentive (firm target) development contract in recent years, evaluating performance and identifying lessons learned would be illustrative, important for informing decision makers, and help guide and improve future defense acquisition programs.

The Department of Defense agreed with the recommendation and compiled lessons learned during the source selection phase of the program. However, the department has not yet identified and reported on lessons learned during program implementation to evaluate cost, schedule, and performance outcomes as we recommended. Program officials said they are collecting lessons learned, but will not report them until after the development contract is complete in 2021. However, by waiting until 2021, other acquisition programs considering using a similar approach will not be able to take advantage of KC-46 lessons learned, including the ones we identify below that could reduce government risk and save taxpayer money.

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### Fixed-Price Incentive Contract and Several Key Clauses Benefitted the Air Force by Limiting the Government's Financial Risk

The Air Force used a fixed-price incentive (firm target) contract type to limit the government's financial risk for KC-46 development. The KC-46

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<sup>11</sup>GAO, *KC-46 Tanker Aircraft: Acquisition Plans Have Good Features but Contain Schedule Risk*, [GAO-12-366](#) (Washington, D.C.: Mar. 26, 2012).

development contract was designed to provide a profit incentive for Boeing to control or even reduce overall costs.

The use of a fixed-price contract did not result in a reduction in development costs below target costs, but did help control the government's costs. Specifically, the Air Force was able to avoid \$1.3 billion in costs exceeding the contract ceiling that Boeing has incurred while developing the aircraft, according to program officials, as of February 2019.

Boeing initially declared cost overruns related to wiring while manufacturing the first development aircraft in the spring of 2014. At that time, it discovered wire separation issues, which were caused by an inaccurate wiring design.<sup>12</sup> It took Boeing about 6 months to correct the wiring design and resume wiring work on the developmental aircraft. Boeing declared other cost overruns later in development as it faced challenges in obtaining Federal Aviation Administration certification for the aircraft, which caused significant testing delays. Together, the wiring problems, certification and testing delays, and other setbacks have resulted in a projected 3-year schedule delay. To the extent these costs exceeded the contract ceiling price, Boeing has borne the costs to address these issues, which included retaining more personnel such as design engineers and testers than it originally planned.

The KC-46 contract also contains three specific clauses that further benefited the government by limiting its financial risk:

- **Correction of deficiencies clause:** This clause requires Boeing to pay for aircraft retrofits when the government determines that the company is not meeting contract specifications. According to the development contract, Boeing is responsible for correcting deficiencies discovered during engineering and manufacturing development, and in production and deployment.<sup>13</sup> Based on the initial

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<sup>12</sup>Wires improperly separated can compromise system redundancies and cause electromagnetic interference. For example, if wires of a redundant system are not properly separated, a single fault could disable multiple systems.

<sup>13</sup>This responsibility includes the periods of integrated test through initial operational test and evaluation or after collection of receiver certification data for 19 receiver aircraft pairings, whichever occurs last. Boeing is also responsible for updating all delivered KC-46 weapon system components and associated documentation, and yet-to-be delivered KC-46 weapon system components exercised under the contract to reflect the production configuration of the aircraft established at the final physical configuration audit.

schedule, operational testing would have ended in 2017. Up to 19 low-rate initial production aircraft would have been covered by this clause and deficiencies would have been almost exclusively identified through testing activities.

Because of delays in the development phase, more aircraft will now be covered by the correction of deficiencies clause. According to the integrated master schedule, Boeing will still be completing development activities in 2020. As a result, the correction of deficiencies clause is expected to now cover the 52 low-rate production aircraft already ordered as well as any other aircraft ordered while development activities are ongoing. Boeing will now be responsible for correcting deficiencies identified during testing as well as in day-to-day operations on all of these aircraft.

- **Fuel usage rate clause:** This clause requires Boeing to meet a specified fuel usage rate for each individual aircraft, which will help the Air Force control some of the KC-46's life cycle costs. According to the contract clause, if an individual aircraft does not meet the fuel usage rate, Boeing would have to propose a corrective action at no cost to the Air Force. The Air Force could also make an equitable price adjustment based on a formula that projects the additional costs the Air Force would incur over the expected 40-year life of the aircraft.
- **Long-term pricing:** The KC-46 contract includes long-term pricing terms for 175 production aircraft. In agreeing to these terms, Boeing had to estimate its costs through 2027. The pricing in the contract protects the government from cost increases including inflation and higher supplier costs that were not already embedded in the prices. The contract includes a variety of purchasing options so that the Air Force is not locked into acquiring a set amount of aircraft each year. It identifies the most cost effective approach for procuring the 175 production aircraft, which is typically between 12 and 15 aircraft for each production lot. It also identifies the additional costs the Air Force would incur if it procured fewer or more aircraft in each production lot that would deviate from the most cost effective approach. Program officials stated that including the long-term pricing in the contract has helped it secure adequate funding from Congress to procure the most cost effective number of aircraft in each of the four low-rate production lots it has awarded so far.

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## Several Provisions of the Fixed-Price Incentive Contract Magnified Program Challenges

Several aspects of the fixed-price incentive development contract, however, did not reduce risk to the government and further complicated existing program challenges. First, production lot awards were not linked to Boeing's performance. Second, progress payments to Boeing were based on costs the contractor incurred rather than on its demonstrated performance. Third, the contract did not identify the timing of when production aircraft would be delivered to the Air Force for acceptance.

- Production lot awards are not tied to demonstrated performance: The development contract linked the award of production lots to schedule milestones rather than to contractor performance. The contract specified that the first and second low-rate production lots had to be awarded within 30 days and 14 months of the low-rate initial production decision, respectively. According to the initial plan, Boeing would have completed 13 months of developmental testing and 66 percent of the flight test program with the KC-46 by the low-rate initial production decision.

As we have previously reported, however, the program experienced delays. At the time of the low-rate initial production decision, the program had only completed about one-third of the planned flight test program. The Air Force decided to award both low-rate production lots within a week of the decision despite the lower amount of testing knowledge. Program officials stated that they awarded the contract because Boeing met the low-rate decision criteria, including demonstrating successful refueling operations. Further, based on the correction of deficiencies clause, they believed at that time that Boeing would be responsible for paying to correct all deficiencies it discovered during subsequent testing on aircraft it produced. Our prior work on best practices, however, emphasizes that awarding production lots before performance is demonstrated introduces risk of cost increases, schedule delays, and performance problems.<sup>14</sup>

- Progress payments are not based on demonstrated performance: The KC-46 contract included a financing approach that requires the Air

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<sup>14</sup>GAO, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Knowledge*, [GAO-02-701](#) (Washington, D.C.: July 15, 2002).



Force to make progress payments to Boeing up to 80 percent of its incurred costs. These progress payments incentivized Boeing to make progress on building the aircraft, and the program's withholding of some payment incentivizes the company to resolve deficiencies more quickly. In general, Department of Defense guidance recognizes that performance-based payments incentivize a contractor to optimize its activities to meet the goals that are important to the government, such as completing a certain amount of engineering or developmental testing by specific milestones.<sup>15</sup> It also notes that they are not practical on all contracts, and contracting officers should consider whether the benefits outweigh the time and effort to establish and administer them. The guidance also notes that progress payments based on costs incurred by a contractor may not reflect the contractor's progress towards meeting program goals or incentivize a contractor to meet those goals. On the KC-46 for example, the program office had made 80 percent of the allowed progress payments for the four development aircraft by November 2015—9 months before the low-rate initial production decision, despite only completing 15 percent of the flight test points at that time.

KC-46 program officials said that once the low-rate production contracts were awarded in August 2016, Boeing prioritized completing the manufacturing of those aircraft because it had previously started manufacturing them with its own funds. It also focused on completing aspects of developmental testing related to the boom and centerline drogue so that it could begin delivering aircraft to the Air Force. In general, once the Air Force accepts an aircraft, Boeing is eligible to receive additional payment for its work on that aircraft. Program officials, however, would have preferred that Boeing placed more emphasis on completing receiver aircraft certifications so that when aircraft were accepted, the Air Force could begin operational testing, which is led and paid for by the government.

- Contract originally did not identify aircraft delivery time frames: The original development contract did not identify a specific delivery period for production aircraft. Instead, it specified that Boeing was supposed to deliver the first 18 aircraft by August 2017. According to program officials, not identifying a delivery period was an oversight. Program officials stated that the Air Force needed more specific aircraft delivery information to develop detailed plans for establishing operating bases and performing depot maintenance, including training

<sup>15</sup>Defense Procurement and Acquisition Policy (Cost, Pricing, and Finance), *Department of Defense Performance Based Payments Guide* (2014).

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pilots and maintainers. For example, if training is done too early, the Air Force may have to provide refresher training to pilots and maintainers. If it is done too late, then the Air Force may not be able to use the aircraft as soon as it could or to the extent it had planned. The Air Force was eventually able to get specific delivery dates for the aircraft as part of negotiations it had with Boeing to modify the development contract after Boeing did not meet the original August 2017 contract delivery date.

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### KC-46 Program Officials Identified Other Key Insights for Successful Implementation of Fixed-Price Incentive Development Contracts

According to current and former KC-46 program officials, stable requirements and a skilled acquisition workforce are essential for executing a fixed-price incentive contract.

- **Stable Requirements:** The current KC-46 program manager said that there were no major requirements changes on the program between 2011 and 2018. The only requirements change occurred in 2019 to address the critical deficiency identified on the boom which, as we discussed earlier, the Air Force is paying to fix. As we previously found in 2012, controls were put in place to limit requirements changes.<sup>16</sup> These controls were in response to a 2011 memorandum issued by the Office of Cost Assessment and Program Evaluation in the Office of the Secretary of Defense. The memorandum maintained that, on the whole, the Department of Defense had demonstrated limited ability to maintain stable requirements and limit changes to program baselines on previous complex weapon system programs, and that minimizing such change would be essential to the success of the KC-46. For the KC-46 program, any engineering or contract changes affecting system requirements or that have the potential to impact program cost, schedule, and performance baselines must be approved by the Air Force Service Acquisition Executive in consultation with the Secretary and the Chief of Staff of the Air Force.
- **Skilled Acquisition Workforce:** Some current and former program managers also noted that having personnel with strong negotiating and cost estimating skills, as well as data rights expertise, is essential

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<sup>16</sup>[GAO-12-366](#).

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for programs with fixed-price incentive development contracts. One former program official explained that in general, contractors such as Boeing on the KC-46 do not know exactly how they are going to build a weapon system until they have completed detailed systems engineering and design drawings, which occurs in the development phase. We previously found in November 2016 that as top-level capability requirements are defined and decomposed into lower-level design requirements, they become more specific and the number of requirements grows.<sup>17</sup> This growth can be exponential, with tens of thousands of detailed design requirements derived from a relatively small number of capability requirements.

While the government generally does not specify how a contractor designs a weapon system for fixed-price incentive contracts, officials we spoke with said KC-46 program managers and engineers have been involved in almost daily discussions with Boeing to make design tradeoffs. As such, one former program executive officer said program offices that are using fixed-price incentive development contracts should ensure that program management staff, including contracting officers and engineers, has strong negotiating skills to protect the government's interest during these daily negotiations where design tradeoffs are made. Further, these program offices need financial management staff with strong cost estimating skills to support the negotiations when necessary. This official indicated that the KC-46 program office had people with these skills.

However, several former program officials stated that the KC-46 program office needed personnel with data rights expertise. They said that they had to rely on a data rights expert from outside the KC-46 program to assist in drafting a section of the request for proposal that would allow the Air Force to obtain data it would need to maintain KC-46 aircraft. The officials indicated that the Air Force has few data rights experts and that it would be beneficial to have contracting officers and attorneys in the program offices with data rights expertise. For example, program officials anticipate that there will be ongoing discussions and negotiations with Boeing about the type of data it will need for the Air Force to perform depot maintenance activities over the life of the program.

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<sup>17</sup>GAO, *Weapon System Requirements: Detailed Systems Engineering Prior to Product Development Positions Programs for Success*, [GAO-17-77](#) (Washington, D.C.: Nov. 17, 2016).

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## Air Force Is Gaining a Better Understanding of the Benefits and Challenges of Implementing a New Sustainment Approach That Could be Considerations for Future Acquisition Programs

The Air Force plans to use a sustainment approach on the KC-46 that it has not yet used on other aircraft, that presents added complexity, and which Boeing is having difficulty supporting. Under the new approach, the Federal Aviation Administration will certify nearly all parts of the aircraft, including most of the military-unique parts such as the centerline drogue, boom, and wing aerial refueling pods.<sup>18</sup> By certifying through the Federal Aviation Administration, the Air Force expects to take advantage of commercial aircraft updates that occur regularly and to obtain new or refurbished parts for the aircraft through a global parts pool that commercial users of the 767 aircraft rely on to maintain their aircraft. Further, the Air Force, instead of a contractor, will provide product support for the aircraft. Previous commercial derivative aircraft programs, including the KC-10, did not have the Federal Aviation Administration certify military-unique functions such as aerial refueling, and the Air Force has relied on the KC-10 contractor for product support over the lifetime of that program. According to the KC-46 acquisition strategy, Boeing will initially provide product support for the KC-46 for a period of up to 5 years. During that time, the Air Force will gradually take over the responsibility and then maintain the aircraft for the lifetime of the program, which is expected to be 40 years. The KC-46 program's experience in obtaining and maintaining Federal Aviation Administration certification, including participation in the parts pool, can offer insights for future acquisition programs to consider.

The Air Force also required Federal Aviation Administration certification to a greater extent than the Air Force policy in place at the time the development contract was awarded. Specifically, the contract states that the contractor shall obtain Federal Aviation Administration certification for all the aircraft's mission equipment. In cases where this is not workable, the contract says that the contractor must exhaust all possible solutions prior to not obtaining full certification.

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<sup>18</sup>On the KC-46 program, the Federal Aviation Administration is certifying the aerial refueling systems and most military systems except for 11 defensive systems such as military radios.

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As we mentioned earlier in the report, Boeing is having difficulty getting certification for the military-unique portions of the aircraft related to the aerial refueling systems, which has contributed to significant program delays. Boeing's commercial business unit already obtained Federal Aviation Administration certification for the commercial parts of the aircraft. However, according to program officials, Boeing's defense business unit, which is responsible for obtaining certifications for the military-unique parts, was not as well versed on the certification process. We previously reported that, according to Boeing officials, the company and the supplier had underestimated the extent of design drawing details required by the Federal Aviation Administration to certify that the parts conformed to the approved design.<sup>19</sup> The supplier of the wing aerial refueling pods spent several years negotiating agreements with several of its key sub-tier suppliers to obtain the necessary documentation. To reduce the risk of further delays, in 2015, Boeing co-located some of its employees with the supplier to provide technical support to complete the documentation for certification over the past several years.

Based on a study completed by Morgan Borszcz Consulting in 2014, the Air Force expected to benefit from saving up to \$420 million by maintaining the Federal Aviation Administration certification for the KC-46 over the life of the program. Savings were primarily estimated in three areas:

1. \$200 million could be saved by having Boeing maintain responsibility for all design changes on the aircraft, including working with the Federal Aviation Administration to certify design changes and updating instruction manuals based on the changes.
2. \$70 million could be saved by having Boeing address any safety issues identified by the Federal Aviation Administration in Airworthiness Directives.
3. Between \$57 million and \$150 million in costs could be avoided if the Air Force maintains Federal Aviation Administration certifications and does not recertify parts to military standards.

The study also stated that the Air Force could save money by participating in the 767 aircraft parts pool, mentioned above, though it did not specify the amount of savings. The parts pool limits the risk of diminishing manufacturing sources over time and the costs the Air Force

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<sup>19</sup>[GAO-18-353](#) and [GAO-17-370](#).

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typically incurs when qualifying new suppliers. Program officials told us that they decided to use a worldwide 767 parts pool because more than 75 percent of KC-46 parts are expected to be available through that parts pool, which reduces the need for the Air Force to procure these parts in advance and place them in its distribution system. Programs that do not have Federal Aviation Administration certified parts have to find and qualify suppliers for needed parts on their own and they must find and qualify new suppliers if one goes out of business over the operational lifetime of the aircraft. In using the 767 parts pool, the Air Force anticipated readily obtaining parts as needed for maintaining the KC-46 aircraft as well as repairing parts and putting them back into the pool.

Since the time the study was completed, however, program officials have learned that the Air Force cannot put parts back into the parts pool because commercial members of the pool do not want to use repaired or reconditioned parts that were used on Air Force aircraft. As a result, the Air Force will not achieve all of the savings it anticipated. Program officials explained that commercial companies do not fly their aircraft under the same conditions as the Air Force, and these companies believe it is too risky for them to use parts that were once used on a KC-46. Program officials said the Air Force can still purchase parts from the parts pool though. The Air Force can also refurbish and use its own parts as long as the parts and the processes it uses to refurbish the parts meet Federal Aviation Administration certification standards and mechanics are properly certified. However, it remains to be seen if the Air Force can maintain the certifications because it has not yet had to do this on other aircraft and requires adherence to Federal Aviation Administration procedures.

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## Conclusions

The Air Force's approach to building the KC-46 has been somewhat unique—deriving a military aircraft from a commercial model using a fixed-price incentive contract, among other things. After experiencing delays of nearly 3 years, the Air Force started accepting aircraft that can now be used for operational testing and support of worldwide missions. While work remains to ensure that critical deficiencies are corrected, the KC-46 program offers lessons that could be shared with other Department of Defense acquisition programs that are considering using a fixed-price-type development contract or a commercial derivative aircraft regarding contracting for and sustaining weapon systems. In particular, the contract provided substantial protections to the government against

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cost increases that Boeing experienced while developing the aircraft, but it also used a financing approach that did not tie Boeing's performance to completing important program goals. In addition, the Air Force's effort to leverage commercially available parts to reduce sustainment costs created challenges. We previously recommended that the Department of Defense develop and share KC-46 lessons learned for future acquisition programs; however, it does not plan to do so until 2021. By sharing identified lessons now with other program leaders considering fixed-price-type contracts or developing commercial derivative aircraft, programs may be able to increase the effectiveness of any new similar development programs.

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## Recommendation for Executive Action

We are making the following recommendation to the Department of Defense:

The Secretary of Defense should ensure that the KC-46 program office disseminates insights we identified in this report about the KC-46's contracting and sustainment planning experiences for consideration by acquisition programs, in particular those considering a fixed-price-type development contract or a commercial derivative aircraft.

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## Agency Comments

We provided a draft of this product to the Department of Defense for comment. In its comments, reproduced in appendix II, the department concurred with our recommendation, but did not identify the specific actions it would take to implement the recommendation. It also provided, in technical comments, language clarifying that the Air Mobility Command cost estimates for flying and maintaining KC-135s longer, as a result of KC-46 delivery delays, did not also account for any savings that would be achieved from not flying KC-46 aircraft. We provided additional detail in the report to address this comment. We also incorporated other technical comments as appropriate.

We are sending copies of this report to the Acting Secretary of Defense, the Acting Secretary of the Air Force, and appropriate congressional committees. The report is also available at no charge on the GAO website at <http://www.gao.gov>.

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If you or your staff have any questions concerning this report, please contact me at (202) 512-4841 or [ludwigsonj@gao.gov](mailto:ludwigsonj@gao.gov). Contact points for our Offices of Congressional Relations and Public Affairs may be found

on the last page of this report. GAO staff who made major contributions to this report are listed in appendix III.

A handwritten signature in black ink, reading "Jon Ludwigson". The signature is fluid and cursive, with the first name "Jon" being more prominent and the last name "Ludwigson" following in a similar style.

Jon Ludwigson  
Acting Director, Contracting and National Security Acquisitions



# Appendix I: KC-46 Performance Capabilities

The program office has 21 performance goals that are critical to the KC-46 aircraft's military capability and track progress to meeting contract specifications. These performance goals include nine key performance parameters, five key system attributes, and seven technical performance measures. Table 2 provides a description of each key performance parameter and key system attribute.

**Table 2: KC-46 Key Performance Parameters and Key System Attributes**

Key performance parameter	Description
Tanker Air Refueling Capability	Aircraft shall be able to effectively conduct (non-simultaneously) both boom and drogue air refueling on the same mission.
Fuel Offload versus Radius	Aircraft shall be capable of carrying certain amounts of fuel (to use in air refueling) certain distances.
Operate in Civil and Military Airspace	Aircraft shall be capable of worldwide flight operations in all civil and military airspace.
Airlift Capability	Aircraft shall be capable of transporting certain amounts of both equipment and personnel.
Receiver Air Refueling Capability	Aircraft shall be capable of receiving air refueling from any compatible tanker aircraft.
Force Protection	Aircraft shall be able to operate in chemical and biological environments.
Net-Ready	Aircraft must be able to have effective information exchanges with many other Department of Defense systems to fully support execution of all necessary missions and activities.
Survivability	Aircraft shall be capable of operating in hostile threat environments.
Simultaneous Multi-Point Refueling	Aircraft shall be capable of simultaneous multi-point drogue refueling.
<b>Key system attribute</b>	
Formation Capability	Aircraft shall be capable of day and night formation flight in weather and all phases of flight.
Aeromedical Evacuation	Aircraft shall be capable of providing air transport for up to 50 patients and medical staff.
Reliability and Maintainability	Able to deploy, operate, sustain, and recover aircraft at sufficient levels of readiness and performance.
Operational Availability	Aircraft shall be operationally available at least 80 percent of the time.
Treaty Compliance Support	Aircraft shall have the necessary hardware installed to demonstrate compliance with applicable treaties.

Source: GAO presentation of Air Force information. | GAO-19-480

Table 3 provides a description and status of each technical performance measure.

**Table 3: KC-46 Technical Performance Capabilities and Statuses**

Technical performance capability	Description	Contract specification or target	Status (meets or projected to meet the measure)
Operational empty weight	Maximum weight of the aircraft without usable fuel.	204,000 pounds	Yes
Fuel usage rate assessment	Maximum gallons of fuel per hour used by the aircraft during a mission.	1,557 gallons per hour	Yes
Mission capable rate	Percentage of time aircraft performed at least one assigned mission.	92 percent	Yes
Fix rate	Percentage of time mechanical problems were fixed within 12 hours (after 50,000 fleet hours).	71 percent	Yes
Break rate	Percentage of breaks per sorties (after 50,000 fleet hours).	1.3 percent	Yes
Mission completion success probability	Probability of completing the aerial refueling mission and landing safely.	99 percent	Yes
Operational availability	Probability an aircraft will be ready for operational use when required.	89 percent	Yes

Source: GAO presentation of Air Force information. | GAO-19-480

## Appendix II: Comments from the Department of Defense



DEPARTMENT OF THE AIR FORCE  
WASHINGTON DC

OFFICE OF THE ASSISTANT SECRETARY

Mr. Jon R. Ludwigson  
Director, Contracting and National Security Acquisitions  
U.S. Government Accountability Office  
441 G Street NW  
Washington DC 20548

30 MAY 2019

Dear Mr. Ludwigson:

This is the Department of Defense (DoD) response to The GAO Draft Report, GAO-19-480, "KC-46 TANKER MODERNIZATION: Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct," dated May 3, 2019 (GAO Code 102925).

The DoD concurs with the GAO's assessment of the KC-46 program as depicted in this report, but with the following recommendation. Page 12 of the report describes costs associated with retaining 28 KC-135 aircraft beyond their planned retirement date to fulfill mission requirements until KC-46 aircraft are fully operational. The Department recommends ensuring that the costs associated with these delayed aircraft retirements also account for the cost avoidance from not operating KC-46 aircraft.

The DoD also concurs with the GAO's single recommendation to disseminate insights identified in the report about the KC-46 program, particularly to those programs considering fixed-price development or the utilization of commercial derivative aircraft.

Sincerely,

A handwritten signature in blue ink, appearing to read "W. B. Roper, Jr.", written over a horizontal line.

William B. Roper, Jr.  
Assistant Secretary of the Air Force  
(Acquisition, Technology & Logistics)

**GAO DRAFT REPORT DATED MAY 3, 2019  
GAO-19-480 (GAO CODE 102925)**

**“KC-46 TANKER MODERNIZATION: Aircraft Delivery Has Begun, but Deficiencies  
Could Affect Operations and Will Take Time to Correct”**

**DEPARTMENT OF DEFENSE COMMENTS  
TO THE GAO RECOMMENDATIONS**

**RECOMMENDATION 1:** The GAO recommends that The Secretary of Defense should ensure that the KC-46 program office disseminates insights we identified in this report about KC-46’s contracting and sustainment planning experiences for consideration by acquisition programs, in particular those considering a fixed-price development contract or a commercial derivative aircraft. (Recommendation 1)

**DoD RESPONSE:** Concur

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# Appendix III: GAO Contact and Staff Acknowledgments

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## GAO Contact

Jon Ludwigson, (202) 512-4841 or [ludwigsonj@gao.gov](mailto:ludwigsonj@gao.gov)

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## Staff Acknowledgments

In addition to the contact named above, Cheryl Andrew, Assistant Director; Lorraine Ettaro; Kurt Gurka; Stephanie Gustafson; Katheryn Hubbell; Jean Lee; Malika Rice; Jenny Shinn; and Steve Woods made key contributions to this report.

# Appendix IV: Accessible Data

## Data Tables

**Data Table for Figure 2: Certifications Needed for Conversion of Boeing 767 into KC-46 Aerial Refueling Tanker**

767-200ER	767-2C provisioned freighter	KC-46 tanker
<ul style="list-style-type: none"><li>• Commercial passenger airplane</li><li>• Type certificate</li></ul>	<ul style="list-style-type: none"><li>• Baseline non-military aircraft</li><li>• Enhanced flight deck</li><li>• Freightier (cargo door &amp; floor)</li><li>• Refueling system and body tanks</li><li>• Tanker system provisions</li><li>• Amended type certificate</li></ul>	<ul style="list-style-type: none"><li>• Aerial refueling components</li><li>• Military avionics</li><li>• Supplemental type certificate</li><li>• Military certification</li></ul>

**Data Table for Figure 3: Planned KC-46 Procurement of 175 Production Aircraft**

Procurement lot	Option exercised (purchased)			Planned (targeted buys)										
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Lot 7	Lot 8	Lot 9	Lot 10	Lot 11	Lot 12	Lot 13	Total lots 13
Number of aircraft per lot	7	12	15	18	15	12	15	12	12	15	15	15	12	Total aircraft 175

**Data Table for Figure 5: Comparison of Original and Current Program Schedules for Delivery of the First 18 Aircraft and All Refueling Systems**

	Delivery of the first aircraft	Delivery of 18 aircraft with all aerial refueling systems
Original 2011 schedule	February 2016	August 2017
Current schedule	January 2019	Jun 2020

**Data Table for Figure 6: Completion Time Frames for KC-46 Test Activities as of March 2019**

	Developmental testing	Operational testing
<b>Aircraft with current boom and centerline drogue system</b>	Completed (September 2018)	Estimated completion (December 2019)
<b>Wing aerial refueling pods</b>	Estimated completion (Early 2020)	Estimated completion (2020)

**Data Table for Figure 7: Status of the KC-46 Receiver Aircraft Testing and Certifications for Operational Testing as of March 2019**

	Receiver aircraft	Testing status	Certification status
Aircraft certified for boom refueling	1.F-16D fighter	Completed	Completed
	2.C-17A transport	Completed	Completed
	3.A-10 attack <sup>a</sup>	Completed	On-going
	4.B-52 bomber	Completed	On-going
	5.F-15E fighter	Completed	On-going
	6.KC-46 tanker <sup>b</sup>	Completed	On-going
	7.F-35A fighter	On-going	Not started
	8.EC-130H electronic attack	On-going	Not started
	9.B-2 bomber	Not started	Not started
	10.F-22A fighter	Not started	Not started
	11.B-1B bomber	Not started	Not started
	12.C-5M transport	Not started	Not started
	13.KC-10A tanker <sup>c</sup>	Not started	Not started
	14.KC-135 R/T tanker	Not started	Not started
	15.EC-130J military information	Not started	Not started
Aircraft certified for centerline drogue refueling	1.F/A-18C/D fighter and attack	Completed	On-going
	2.F/A-18 E/F fighter and attack	Not started	Not started
	3.CV-22 vertical lift transport	Not started	Not started

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## Agency Comment Letter

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### Page 1

Mr. Jon R. Ludwigson

Director, Contracting and National Security Acquisitions

U.S. Government Accountability Office 441 G Street NW

Washington DC 20548

Dear Mr. Ludwigson:

This is the Department of Defense (DoD) response to The GAO Draft Report, GA0-19- 480, "KC-46 TANKER MODERNIZATION: Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct," dated May 3, 2019 (GAO Code 102925).

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The DoD also concurs with the GAO's single recommendation to disseminate insights identified in the report about the KC-46 program, particularly to those programs considering fixed-price development or the utilization of commercial derivative aircraft.

William B. Roper, Jr.

Assistant Secretary of the Air Force

Acquisition, Technology and Logistics



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Page 2

GAO DRAFT REPORT DATED MAY 3, 2019 GAO-19-480 (GAO CODE 102925)

"KC-46 TANKER MODERNIZATION: Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO  
RECOMMENDATIONS

**RECOMMENDATION 1: The GAO recommends that The Secretary of Defense should ensure that the KC-46 program office disseminates insights we identified in this report about KC-46's contracting and sustainment planning experiences for consideration by acquisition programs, in particular those considering a fixed-price development contract or a commercial derivative aircraft. (Recommendation I)**

**DoD RESPONSE: Concur**

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## Related GAO Products

GAO, *KC-46 Tanker Modernization: Program Cost is Stable, but Schedule May Be Further Delayed*, [GAO-18-353](#) (Washington, D.C.: Apr. 18, 2018).

GAO, *KC-46 Tanker Modernization: Delivery of First Fully Capable Aircraft Has Been Delayed Over One Year and Additional Delays are Possible*, [GAO-17-370](#) (Washington, D.C.: Mar. 24, 2017).

GAO, *KC-46 Tanker Aircraft: Challenging Testing and Delivery Schedules Lie Ahead*, [GAO-16-346](#) (Washington, D.C.: Apr. 8, 2016).

GAO, *KC-46 Tanker Aircraft: Key Aerial Refueling Capabilities Should Be Demonstrated Prior to the Production Decision*, [GAO-15-308](#) (Washington, D.C.: Apr. 9, 2015).

GAO, *KC-46 Tanker Aircraft: Program Generally on Track, but Upcoming Schedule Remains Challenging*, [GAO-14-190](#) (Washington, D.C.: Apr. 10, 2014).

GAO, *KC-46 Tanker Aircraft: Program Generally Stable but Improvements in Managing Schedule Are Needed*, [GAO-13-258](#) (Washington, D.C.: Feb. 27, 2013).

GAO, *KC-46 Tanker Aircraft: Acquisition Plans Have Good Features but Contain Schedule Risk*, [GAO-12-366](#) (Washington, D.C.: Mar. 26, 2012).

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