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January 2022

KC-46 TANKER

Air Force Needs to Mature Critical Technologies in New Aerial Refueling System Design

GAO-22-104530

GAO Highlights

Highlights of GAO-22-104530, a report to congressional addressees

January 2022

KC-46 TANKER

Air Force Needs to Mature Critical Technologies in New Aerial Refueling System Design

Why GAO Did This Study

The KC-46 tanker is among the Air Force's highest acquisition priorities as it is intended to replace one-third of the aging aerial refueling tanker fleet. Aerial refueling—the transfer of fuel from airborne tankers to combat and airlift forces while in flight—is critical to the U.S. military's ability to operate globally.

GAO received a request to review the KC-46 program. In addition, a House Report included a provision for GAO to review the Department of Defense's (DOD) use of contracted aerial refueling services. This report reviews the KC-46 program and assesses: (1) the Air Force and Boeing's steps to address critical deficiencies; (2) the Air Force's plans to conduct a technology readiness assessment and maturation plan for critical technologies; and (3) DOD's actions to address potential aerial refueling gaps, including the use of contracted refueling services.

GAO assessed documentation and interviewed officials from the KC-46 program office, Air Force, DOD, and Boeing, among others.

What GAO Recommends

GAO is making three recommendations including that, prior to the approving the contractor's redesign of the remote vision system, or soon thereafter, the Air Force (1) assess technology readiness, (2) develop a technology maturation plan, and (3) test the prototype in an operational environment. The Air Force did not concur with these recommendations. GAO continues to believe these recommendations are valid, as discussed in this report.

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What GAO Found

The KC-46 tanker's aerial refueling capability enables military aircraft to fly farther and stay airborne longer. The Air Force and Boeing are currently addressing several critical deficiencies—such shortfalls that can cause death or injury, or loss or damage to the aircraft—that are delaying use of KC-46's full aerial refueling capabilities. Two of these deficiencies relate to the aircraft's remote vision system (RVS). The system's cameras and display allow operators to observe and reposition the boom—a rigid telescope that delivers fuel to the receiver aircraft. (See figure.) The RVS currently cannot be used to perform all aerial refueling missions because it does not work in changing lighting conditions.

KC-46 Aircraft Using a Boom to Refuel a Receiver Aircraft

Source: © 2016 Boeing Company - Photo by Paul Weatherman. | GAO-22-104530

Despite delays, the government's financial risk has generally been limited to the ceiling price of its contract with Boeing. However, the Air Force plans to close its review of the contractor's proposed redesign for the remote vision system and assume financial responsibility for it without:

- assessing the system's technology readiness level;
- developing a plan to bring the system's immature technologies to appropriate technology readiness levels; and
- integrating and testing the system prototype in an operational environment.

Without taking these steps prior to closing the preliminary design review, the program may accept a remote vision system design that contains immature technologies and greater risk of cost and schedule growth. The sooner the program completes these steps, even if after the design review, the sooner it can identify design issues and proactively take steps to mitigate any further cost growth and delays in delivering promised capability to the warfighter.

As the Air Force begins to retire its aging tankers, it plans to expand the use of KC-46s while it works to address the remote vision system and other shortfalls. It is also studying the use of contracted air refueling services to add future capacity should there be shortages. The Air Force expects to complete that study in 2023.

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Abbreviations

AMC	Air Mobility Command
DOD	Department of Defense
DON	Department of the Navy
FAR	Federal Acquisition Regulation
ICR	interim capability release
LWIR	long-wave infrared
Omega	Omega Air Refueling Services
RFP	request for proposal
RVS	remote vision system
TMP	technology maturation plan
TRA	technology readiness assessment
TRL	technology readiness level
USTRANSCOM	United States Transportation Command

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Congressional Addressees

The KC-46 aerial refueling tanker program, initially estimated to cost about $51.7 billion, is among the Air Force's highest acquisition priorities, and will eventually replace one-third of the Air Force's fleet of aging aerial refueling tankers. Aerial refueling—the transfer of fuel from airborne tankers to combat and other aircraft—is critical to the U.S. military's ability to effectively operate around the globe. Aerial refueling enables military aircraft to fly farther, stay airborne longer, and carry more weapons, equipment, and supplies than they could without this service.

In February 2011, the Air Force awarded a contract to Boeing to modify the design of a commercial aircraft—the Boeing 767—into a military aerial refueling tanker, the KC-46. However, several critical deficiencies with the refueling system have delayed the completion of the development portion of this program. Critical deficiencies are shortfalls that could cause death, severe injury, or illness, or otherwise cause loss or damage to the aircraft. Under the original contract, Boeing was required to deliver 18 KC-46 tankers in the final production configuration by August 2017, but these critical deficiencies have prevented Boeing from doing so, which has limited the KC-46's refueling capacity to date. Specifically, the National Defense Authorization Act for Fiscal Year 2021 generally prohibited the Air Force from retiring any additional KC-135s and required the Air Force to maintain at least 26 KC-10s through fiscal year 2023. Furthermore, the Air Force is evaluating the viability of a contracted aerial refueling program to supplement the Air Force's tanker fleet by supporting training missions. The Navy has been using contracted aerial refueling services to support its training needs for about 20 years.

We were asked to review the KC-46 program, including the status of correcting the critical deficiencies. In addition, House Report 116-442, accompanying a bill for the Fiscal Year 2021 National Defense Authorization Act, included a provision for us to review the Department of Defense's (DOD) use of contracted aerial refueling services. This report assesses the extent to which (1) the Air Force and Boeing have taken steps to address critical deficiencies and meet cost and schedule goals; (2) the Air Force completed a technology readiness assessment and a maturation plan for critical technologies in the aerial refueling system; and (3) the Air Mobility Command (AMC) has identified aerial refueling capacity gaps due to delays in KC-46, and the actions DOD has taken to

address any gaps, including the use of contracted services. This is our ninth report on the KC-46 program. See the Related GAO Products page for a list of our previous KC-46 reports.

To address all of our objectives, we assessed documentation, including critical deficiency reports, the KC-46 acquisition program baseline, the KC-46 contract and modifications, and Navy contract data for aerial refueling services from 2013 through 2021. To ensure the Navy contract data were sufficiently reliable for this review, we reviewed documents for the Navy's Contracted Air Services database, assessed responses from Navy officials to questions about the data system, and sent the results of our analysis to the Navy and the sole-source contractor of aerial refueling services for confirmation. We also interviewed officials and representatives from the KC-46 program office; Offices of the Director of Operational Test and Evaluation and the Director of Developmental Test and Evaluation; the Boeing Company; the Office of the Assistant Secretary of the Air Force for Acquisition, Technology and Logistics; U.S. Transportation Command (USTRANSCOM); AMC; and Naval Air Systems Command (NAVAIR), among others. See appendix I for a detailed description of our objectives, scope and methodology.

We conducted this performance audit from September 2020 to January 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Air Force's Aerial Refueling Fleet and USTRANSCOM and AMC Roles

The Air Force's existing fleet of 442 legacy tankers—392 KC-135 and 50 KC-10 aircraft—and the new KC-46 tankers—eventually totaling 179 aircraft—account for the bulk of the DOD's aerial refueling capability. The KC-135 and KC-10 tankers, averaging roughly 60 and 35 years old, respectively, are becoming costly to maintain and one-third are scheduled to be retired. For example, according to an AMC official, the Air Force plans to retire all 50 KC-10s by the end of fiscal year 2024. The Air Force had originally planned to replace one-third of the tankers scheduled for retirement with the KC-46 tankers beginning in 2017.

The Air Force's aerial refueling fleet's activities are generally managed by USTRANSCOM and AMC. USTRANSCOM is the DOD combatant

command that provides air, land, and sea transportation to accomplish DOD's global mobility missions, including aerial refueling.[1] AMC is the Air Force component of USTRANSCOM and executes the majority of DOD's inter-theater airlift and aerial refueling missions. In addition, AMC establishes and maintains training programs on behalf of the Air Force, and advocates for mobility in the Air Force planning, programming, budgeting, and execution process, to include the identification of future mobility modernization demands.

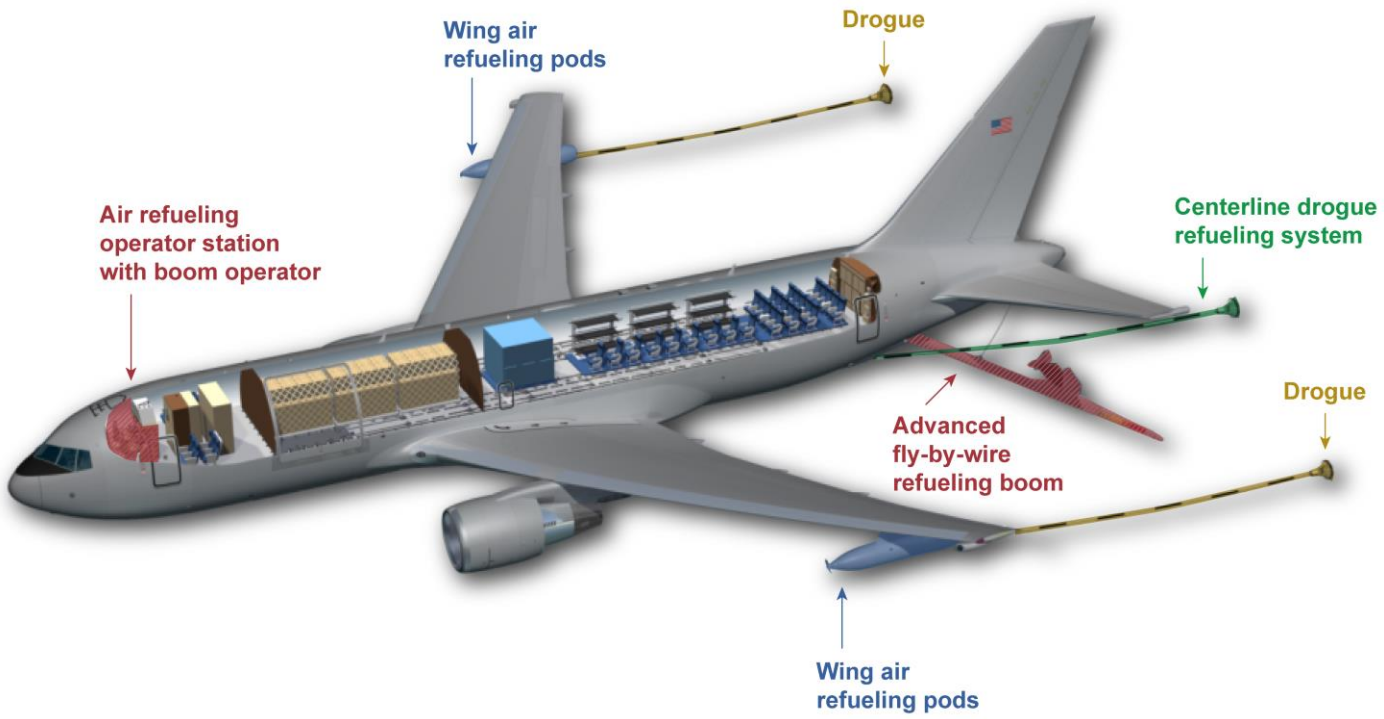
KC-46 Missions and Capabilities

The KC-46 was designed to perform a wide range of missions. For example, the aircraft includes a large cargo door for transporting of large objects or other cargo. It can also be reconfigured to provide transport for seated personnel and aeromedical evacuation.

The KC-46 is also designed to perform aerial refueling of a wide range of aircraft and is 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 from legacy 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. Figure 1 shows the boom and drogue refueling subsystems on the KC-46.

[1]USTRANSCOM and AMC do not have authority over the KC-130J and KC-130T operated by the Navy and Marine Corps. These aircraft are capable of aerial refueling, but have a broader mission profile that also includes reconnaissance and close-air support.

Figure 1: KC-46 Aerial Refueling Subsystems



Source: GAO representation of a 2014 Boeing image. | GAO-22-104530

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.

Boom refueling. During boom refueling, the pilot of the receiving aircraft flies the aircraft into position near the end of the boom—a rigid, telescoping tube. An operator on the KC-46 then extends the boom and inserts it into a receptacle on the receiver aircraft. The KC-46 uses a different system than legacy tankers for the boom. On legacy tankers, boom operators lie face down or sit to view the position of the boom and the receiver aircraft through a window in the belly of the plane. In contrast, the KC-46 uses what is called the remote vision system (RVS). The RVS allows operators to observe the position of the boom and the receiver aircraft, and to reposition the fuel delivery system to facilitate refueling, from a seated position at a station near the cockpit of the aircraft using cameras and displays. There are three critical technologies—elements that the system depends on to meet operational requirements—of the RVS:

1. Visible camera: the pair of cameras used by the boom operator to affect contact between the boom and receiver aircraft;
2. Long-wave infrared boom camera: the pair of cameras that allows the boom operator to conduct refueling operations without the use of visible lighting, generally in covert environments; and
3. Primary display: the display that projects a three-dimensional image of the receiver aircraft captured by the visible and long-wave infrared cameras to the boom operator.

In 2017 and 2018, the Air Force identified one critical deficiency with the KC-46 boom and two critical deficiencies with the RVS. As a result of these critical deficiencies, the Air Force restricted the KC-46 from certain boom refueling operations until these deficiencies are fixed. According to AMC officials, at present the KC-46 is being used mostly to train aircraft and refueling crews, including training for boom refueling. We discuss these deficiencies and Boeing's and the Air Force's efforts to address them later in the report. See figure 2 of a KC-46 tanker using a boom to refuel a receiver aircraft.

Figure 2: KC-46 Aircraft Using a Boom to Refuel a Receiver Aircraft

Source: © 2016 Boeing Company - Photo by Paul Weatherman. | GAO-22-104530

Hose-and-drogue refueling. The drogue refueling system—comprised of a long, flexible refueling hose and a parachute-like metal basket used

to provide stability—is available via the centerline drogue system in the middle of the aircraft or via wing aerial refueling pods located on each wing. The operator uses the RVS to identify when to extend or reel in the hoses. The wing pods allow the KC-46 to simultaneously refuel two Navy or allied aircraft, which is an enhancement over most of the legacy tankers.[2] See figure 3 of a KC-46 tanker using the centerline drogue system to refuel a receiver aircraft.

Figure 3: KC-46 Aircraft Using the Centerline Drogue System to Refuel a Receiver Aircraft

Source: U.S. Navy. | GAO-22-104530

Tanker Replacement and KC-46 Contract History

The Air Force made a few efforts to replace its aerial refueling tanker capability before committing to the development of the KC-46. These included efforts to lease airborne tankers and to contract for development of a military tanker from a different commercial company.

- In 2002, Congress authorized a pilot program for the Air Force to lease up to 100 Boeing 767 aircraft modified for aerial refueling,

[2]A limited number of legacy tankers can be equipped with wing pods.

subsequently called the KC-767A aircraft.[3] This lease was ultimately canceled, however, after a DOD investigation found that a senior Air Force official improperly approved the leasing proposal.

- In 2006, the Air Force completed an analysis of alternatives to identify solutions for replacing existing tankers and determined that modifying a tanker based on a commercial aircraft would be the most cost-effective solution.[4]
- In January 2007, DOD issued a request for proposal (RFP) to procure 179 such tankers.[5] The RFP contemplated that the successful offeror would build four aircraft for testing and up to 80 aircraft under the initial contract. On February 29, 2008, the Air Force awarded the contract to Northrop Grumman Systems Corporation for the KC-45. Boeing, the competing offeror, filed a protest with GAO protesting the Air Force's decision.[6] In June 2008, we determined that the Air Force had made significant errors, including not assessing the relative merits of the proposals in accordance with the evaluation rules and criteria set out in the RFP, which could have affected the outcome of the competition.[7] As a result, the Office of the Secretary of Defense directed the Air Force in September 2008 to terminate the contract and conduct a new competition.

In February 2010, the Air Force released a significantly revised RFP for a new air fueling tanker. In February 2011, the Air Force awarded Boeing a fixed-price incentive (firm target) contract to develop the new KC-46s, and the program initially estimated the total acquisition cost at $51.7 billion. The fixed-price incentive contract required Boeing to first develop and deliver four test aircraft. In addition, the contract included options for Boeing to manufacture 175 additional aircraft with firm-fixed-price contract options for the first two production lots, and options with not-to-exceed

[3]Pub. L. No. 107-117, § 8159 (2002).

[4]An analysis of alternatives is a key element of the defense acquisition process. It is an analytical comparison of the operational effectiveness, suitability, and life-cycle cost (or total ownership cost, if applicable) of alternatives that satisfy established capability needs.

[5]The Federal Acquisition Regulation (FAR) provides for the use of RFPs in negotiated acquisitions to communicate government requirements to prospective contractors and to solicit proposals. FAR 15.203(a).

[6]A protest is a written objection by an interested party regarding, among other things, the terms of a solicitation or the award of a federal contract. GAO's Procurement Law Division is one of several venues for filing these protests. For more information on GAO's role in bid protests, visit https://www.gao.gov/legal/bid-protests.

[7]*The Boeing Co.*, B-311344 et al., June 18, 2008, 2008 CPD ¶ 114.

fixed prices for production lots 3 through 13. For the purposes of this report, a production lot refers to a specific number of aircraft defined in the contract that must be built and delivered in a given time frame and procured with a specific year of budget funding with a specified price. The Air Force exercised the first of these options in 2016. In January 2021, the Air Force exercised the seventh and most recent contract option, bringing the total number of production aircraft to 94, and plans to exercise another six contract options for the remaining 81 aircraft by fiscal year 2027.

The Air Force used a fixed-price incentive (firm target) 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.[8] 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 share is 40 percent. Cost sharing ended when the contract price reached the $4.9 billion ceiling. Thereafter, Boeing is responsible for all additional costs associated with the overruns. In March 2012, we reported that assuming no systems requirement changes, the Air Force's decision to use a fixed-price incentive (firm target) contract limited the government's cost liability.[9] Because the KC-46 program was one of only a few major acquisition programs with this contract type at the time, we also made a recommendation to share lessons learned from the program, which the Assistant Secretary of the Air Force for Acquisition, Technology and Logistics implemented in December 2020.

[8]A fixed-price incentive (firm target) contract specifies a target cost, a target profit, a price ceiling (but not a profit ceiling or floor), and a profit adjustment formula. These elements are all negotiated at the outset. The price ceiling is the maximum that may be paid to the contractor, except for any adjustment under other contract clauses. When the contractor completes performance, the parties negotiate the final cost, and the final price is established by applying the formula. When the final cost is less than the target cost, application of the formula results in a final profit greater than the target profit; conversely, when final cost is more than target cost, application of the formula results in a final profit less than the target profit, or even a net loss. If the final negotiated cost exceeds the price ceiling, the contractor absorbs the difference as a loss. Because the profit varies inversely with the cost, this contract type provides a positive, calculable profit incentive for the contractor to control costs. FAR 16.403-1(a).

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

As we reported in 2019, the contract contained key provisions related to design specifications and correction of deficiencies. For example, the contract specified that the RVS should provide sufficient visual clarity in all lighting conditions. The contract also specified 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 to absorbing the costs for these fixes, as Boeing has fallen further behind schedule, Boeing has provided the Air Force non-financial considerations—an item or service that is negotiated between the government and contractor—to offset the loss of military tanker capacity resulting from KC-46 delays. Program officials said the Air Force received eight non-financial considerations from Boeing for the program's production, development, training, and testing. In February 2021, officials said, four of these considerations were ongoing and the other four were completed. For example, according to Air Force officials, Boeing provided the Air Force with support equipment for the KC-46's receiver aircraft testing activities through December 2020.

In addition, the contract required the Air Force to make progress payments to Boeing of up to 80 percent of incurred costs to complete aircraft on order. We reported in 2019 that the Air Force had been withholding the remaining 20 percent until all deficiencies were corrected on delivered aircraft to provide Boeing with an incentive to quickly resolve these deficiencies. However, in April 2020, the Air Force authorized the release of $882 million to Boeing that had been withheld for this purpose to assist the company with supply issues stemming from the Coronavirus Disease 2019.

Critical Deficiencies Continue to Drive Schedule Delays and Cost Increases

The Air Force and Boeing are currently addressing seven critical deficiencies, which will delay the KC-46 program's full-rate production milestone to at least September 2024 and will contribute to nearly $1 billion in cost growth. However, the Air Force will have procured the majority of KC-46 aircraft, which will be used in limited operations, before the critical deficiencies are addressed and the program enters full-rate production. Three of these critical deficiencies are related the KC-46's aerial refueling system—specifically the RVS and boom—and those deficiencies are not expected to be resolved until 2024 and 2023, respectively. These deficiencies have led to a delay in the full-rate production decision by about 4 years from its previous baseline, until at least September 2024. These critical deficiencies have also contributed to a nearly $1 billion increase in acquisition cost since 2019, due to

redesigning the boom and the Air Force's decision to buy fewer aircraft in the near term and buy more expensive aircraft later.

The Air Force and Boeing Are Currently Addressing Seven Critical Deficiencies with the KC-46

The Air Force has identified nine critical deficiencies since 2017. The Air Force and Boeing have resolved two of these and plan to resolve the remaining seven by 2024. Three of the seven unresolved critical deficiencies relate to the KC-46's aerial refueling system and four reflect product quality issues. Table 1 shows each critical deficiency identified since 2017 and resolution dates or dates for expected resolution.

Table 1: KC-46 Critical Deficiencies Identified by the Air Force and Resolution Dates

Critical deficiency	Category	Status	Identification date	Resolution date
Remote vision system visual clarity	Refueling	Open	March 2018	Expected in 2024
Remote vision system undetected contacts	Refueling	Open	May 2017	Expected in 2024
Refueling boom stiffness	Refueling	Open	September 2018	Expected in 2023
Flight management system instability	Product Quality	Open	March 2021	Expected in 2022
Air refueling drain tube cracks	Product Quality	Open	March 2021	Expected in 2022
Drain mast cracks	Product Quality	Open	August 2020	Expected in 2022
Fuel system leaks	Product Quality	Open	March 2020	Expected in 2021
Air duct clamps cracking	Product Quality	Closed	June 2019	January 2021
Cargo pallet locks detachment	Product Quality	Closed	September 2019	December 2019

Source: GAO presentation of KC-46 program information. | GAO-22-104530

Below is more detailed information on the critical deficiencies.

- **Remote vision system.** As we reported in June 2019, the Air Force identified two critical deficiencies with the RVS during developmental testing in 2017 and 2018: (1) the system did not provide visual clarity—or allow the boom operator to see the receptacle sufficiently to make contact with the receiver—in some specific lighting conditions, and (2) the lack of visual clarity also resulted in undetected contacts with some receiver aircraft and, in some cases, damage to the receiver aircraft's coating.[10]

  Specifically, the contract required Boeing to develop the RVS system to be suitable for all lighting conditions. However, the system had difficulty making timely adjustments to changing lighting conditions in

[10]GAO, *KC-46 Tanker Modernization: Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct*, GAO-19-480 (Washington, D.C.: June 12, 2019).

some specific environmental conditions. These conditions include certain sun angles; according to program officials, the glare from the sun would cause the image of the receiver aircraft on the boom operator's display screen to momentarily wash out or black out. In addition to certain sun angles, the boom operator could not differentiate between the boom tip and receiver aircraft at night with the long-wave infrared camera. The inability to see the receiver aircraft can make it difficult for the boom operator to sufficiently see the receptacle of the receiver aircraft to start refueling.

The RVS also does not provide the boom operator with sufficient depth perception to safely refuel in all lighting conditions, which can result in the boom nozzle making undetected contacts outside the refueling receptacle. In June 2019, we reported that the program expected the changes to the RVS system to be made without additional cost to the government because the original system did not meet the requirements in the contract.[11] At that time, Boeing was expected to take 3 to 4 years to develop a solution for the RVS, involving hardware and software revisions, and have it certified by the Federal Aviation Administration.

The Air Force and Boeing, through a memorandum of agreement signed in April 2020 that was later incorporated into the KC-46 contract, agreed on software and hardware design changes for a new RVS to address the critical deficiencies, and they expect to finalize development of a new system by the middle of 2024. We discuss the design maturity of the new remote vision system later in this report. Until the new RVS is developed, Boeing plans to release interim software updates—such as updates to reduce distortion and improve system imagery—to improve the existing system on delivered aircraft.

- **Refueling boom.** As we reported in June 2019, the Air Force identified a critical deficiency with the boom during developmental flight testing in 2018.[12] Specifically, the Air Force found that the original boom was too stiff and hampered the fueling of lighter aircraft, such as the A-10 and F-16. Pilots of these lighter receiver aircraft reported the need to use excessive thrust to move their aircraft into position to release fuel from the boom and maintain the refueling position. This additional required thrust can cause the receiver aircraft

[11]GAO-19-480.

[12]GAO-19-480.

to lunge forward into the boom and strike it, possibly damaging the receiver aircraft and the boom.

In June 2019, we reported that program officials said the Air Force is responsible for all redesign and retrofit costs related to the boom because it agreed to Boeing's proposed stiffness specification—the amount of force needed to compress the boom—in August 2016 at the low-rate initial production decision without fully testing the boom.[13] Similarly, a May 2021 DOD Inspector General report found the Air Force responsible for these costs as KC-46 program officials did not effectively manage the boom's development in accordance with best practices for design maturation. Specifically, the Inspector General found that program officials did not ensure that the boom's critical technologies were demonstrated in a relevant testing environment after Boeing presented a system design at the preliminary design review that differed significantly from its initially proposed design. Furthermore, the Inspector General found that the KC-46 program office did not verify the boom's full functionality in accordance with the program's test plans during receiver aircraft testing activities.

In September 2020, the Air Force signed a contract modification with Boeing to redesign, build, test, and certify a new boom to address the critical deficiency with the boom stiffness. The program expects Boeing to complete development of the new boom in 2023, with additional operational testing to follow, and incorporate the new boom into the production line in fiscal year 2025. Boeing will also retrofit the new boom onto already-delivered aircraft starting in July 2025.

- **Flight management system instability.** In March 2021, the Air Force identified a critical deficiency with the flight management system—which provides flight guidance and navigation support—after error messages occurred on a trans-Pacific flight. Program officials said Boeing is working with General Electric Aviation—the subcontractor—to develop a software fix for the instability issue, and that they plan to release it to fielded aircraft by September 2022. In the meantime, according to program officials, Boeing released procedural guidance for KC-46 aircrews should the errors reoccur.
- **Air refueling drain tube cracks.** In March 2021, the Air Force identified a critical deficiency with the air refueling drain tube, which drains excess fuel in the air refueling receptacle after refueling operations. The program said the drain tube cracked while the aircraft

[13]GAO-19-480.

was flying in freezing temperatures and the water in the receptacle froze and expanded in the receptacle, and that Boeing has determined the root cause. This issue followed two other instances in January and February 2020. Program officials said that Boeing is developing a new drain tube, and they expect to retrofit delivered aircraft beginning in 2022.

- **Drain mast cracks.** In August 2020, during operational test flights, the Air Force identified a critical deficiency with the drain mast—a metal piece outside the back of the airplane that allows the aircraft to drain liquids, such as hydraulic fluids or fuel, in flight. According to program officials, the drain mast was not properly welded and could potentially crack and break off due to the excessive movement. The cracks led to increased aircraft maintenance and operational restrictions for draining excess fluids appropriately. In January 2021, the Air Force downgraded this critical deficiency to a less serious deficiency after Boeing developed an interim solution—a modified drain mast design that will provide longer service life. Boeing retrofitted the interim drain mast on all delivered aircraft, and incorporated it into the KC-46's production line. However, the Air Force elevated the issue to a critical deficiency again in April 2021 after another instance of a drain mast cracking. Program officials said they expect Boeing to complete a final design by early 2022 that would last through the aircraft's service life without replacement. The final design will undergo testing and verification before the Air Force can close the deficiency. After that, Boeing will retrofit delivered aircraft with the final design and incorporate it into the KC-46's production line.
- **Fuel system leaks.** In March 2020, the Air Force identified an excessive amount of fuel leaks in the aircraft's fuel system components during flight tests, which affected the aircraft's availability. Boeing representatives attributed the leaks to a defective seal design, and Boeing is designing a new seal and coupling to address the issue. Program officials said that they planned to incorporate the fix into the KC-46 production line by December 2021 and are currently developing a plan to retrofit delivered aircraft.
- **Air duct clamps cracking.** In June 2019, the Air Force identified a critical deficiency with air duct clamps, each of which is composed of a metal ring that prevents leaks when air moves through the ducts. Specifically, maintenance crews found these clamps to be cracked. Boeing and the Air Force conducted a root cause analysis and found that the cracks may be a result of over-torqueing the clamps during installation. Maintainers removed and replaced cracked clamps and

verified the proper torque value on aircraft delivered through January 9, 2020. Boeing also re-torqued the clamps on all non-delivered aircraft, and updated its production line procedures to the specified torque value. However, in April 2020, maintainers found another 11 instances of failed duct clamps on aircraft delivered after January 10, 2020. After further root cause analysis, Boeing decided to use a more robust clamp designed for the Boeing 777 to replace the original KC-46 air duct clamps. In January 2021, the Air Force closed the critical deficiency. Program officials said, as of September 2021, Boeing had retrofitted all 47 delivered aircraft with the new duct clamp and planned to incorporate this fix into the production line after the next production delivery.

- **Cargo pallet locks detachment.** In September 2019, the Air Force identified a critical deficiency with the cargo pallet locks—which restrain the cargo pallet to the aircraft floor—after they became detached during multiple flight tests. Air Force officials attributed the issue to a poor design because the locks would not stay flush on floor rails and would wobble. Aircrew also had difficulty installing some locks, as they required concentrated force to install on the floor rails. Due to potential flight safety issues, the Air Force restricted cargo and passenger operations until the lock detachment problem was resolved. In December 2019, the Air Force closed the critical deficiency with the cargo pallet lock and rescinded its flight restrictions after Boeing redesigned the lock. As of September 2020, Boeing had retrofitted all delivered aircraft and incorporated the fix in its production line.

Critical Deficiencies with Aerial Refueling System Will Delay Full-Rate Production Decision until at Least 2024

The critical deficiencies related to the aerial refueling system—the RVS and the boom—will result in delays to the KC-46 full-rate production decision—the program's next major production milestone—until at least September 2024, but the Air Force will continue to purchase KC-46 aircraft in the meantime. In October 2020, the program updated its acquisition program baseline to account for an almost 4-year delay of this milestone decision from October 2020 to September 2024 so it could fix the boom and RVS deficiencies. Test officials currently expect to finish developmental testing for these subsystems in September 2023 and April 2024, respectively. The program will then need to complete initial operational test and evaluation to ensure those subsystems meet requirements and that the deficiencies are fully resolved. According to test officials, they plan to complete initial operational test and evaluation activities on the new RVS and boom with receiver aircraft beginning in late 2023 through May 2024, assuming development remains on track, to

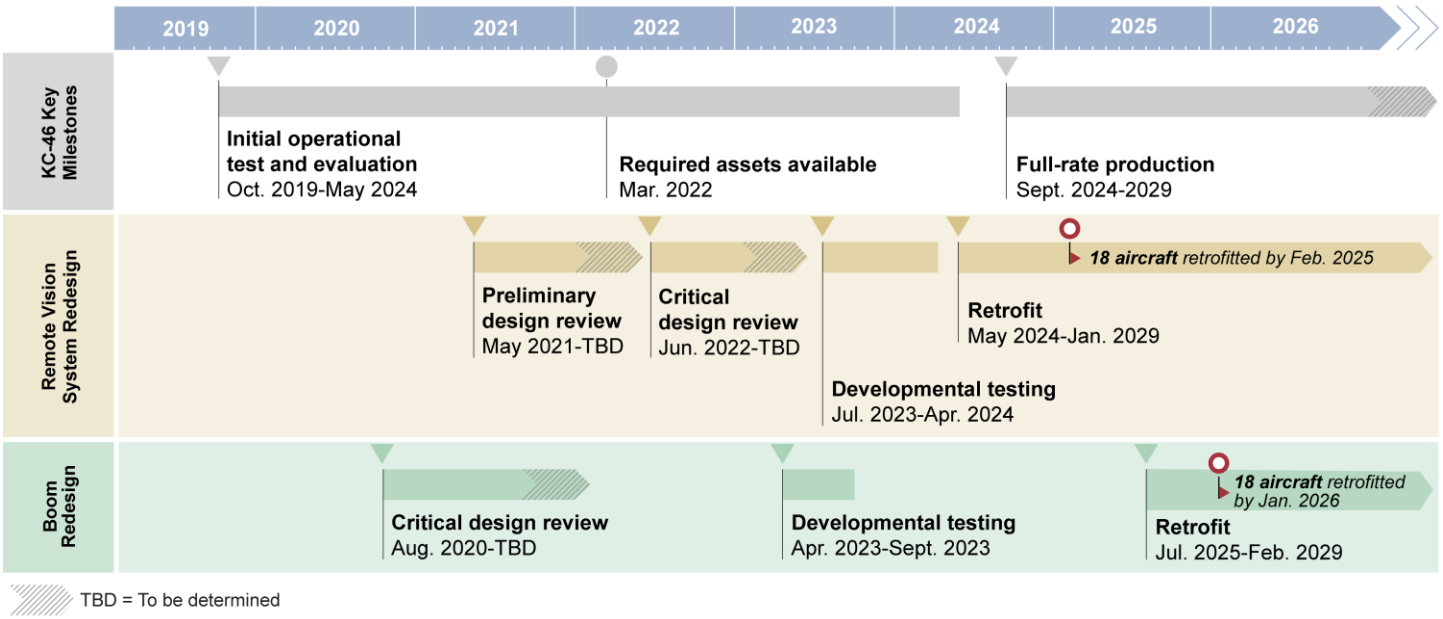
ensure these subsystems meet requirements. The program then plans to make a full-rate production decision by September 2024.

In addition, the program also updated the required assets available date in its 2020 acquisition program baseline to account for about a 1-year delay in this milestone from February 2021 to March 2022. Required assets available is the delivery of 18 aircraft in their final production configuration, as well as nine sets of wing aerial refueling pods and two spare engines.[14] We determined, however, that the March 2022 date does not account for the current development and retrofit schedule for the RVS and boom. Specifically, the Air Force projects the retrofit for the new remote vision system on the first 18 aircraft to span 9 months, from May 2024 through February 2025. The Air Force also projects the retrofit schedule for the new boom on the first 18 aircraft to start almost 2 years after finalizing the design in September 2023, and to take roughly 6 months, from July 2025 through January 2026. Given these estimates, the 18 aircraft in the final production configuration with the new boom and RVS will not be available until after January 2026.

Program officials said that the milestone dates are constantly changing due to uncertainty with the development, testing, and retrofitting of the new RVS and boom. They said they are in the process of determining whether an update is needed to the acquisition program baseline to reflect schedule delays, and will take the appropriate steps to update the acquisition program baseline if required. Figure 4 shows the program's estimated time frames for key milestones and the RVS and boom development and retrofit schedules.

[14]The Air Force is using the terminology of "final production configuration" in its acquisition program baseline as a surrogate for the contractual term "final product baseline". For the purpose of this report, we refer to them both as final production configuration. Program officials said that final production configuration is constantly evolving. They said that the final production configuration does not currently include the new RVS and new boom designs, but that the program intends to include them before meeting the required assets available milestone date.

Figure 4: Current KC-46 Key Milestones and Schedule for Redesigned Remote Vision System and Boom



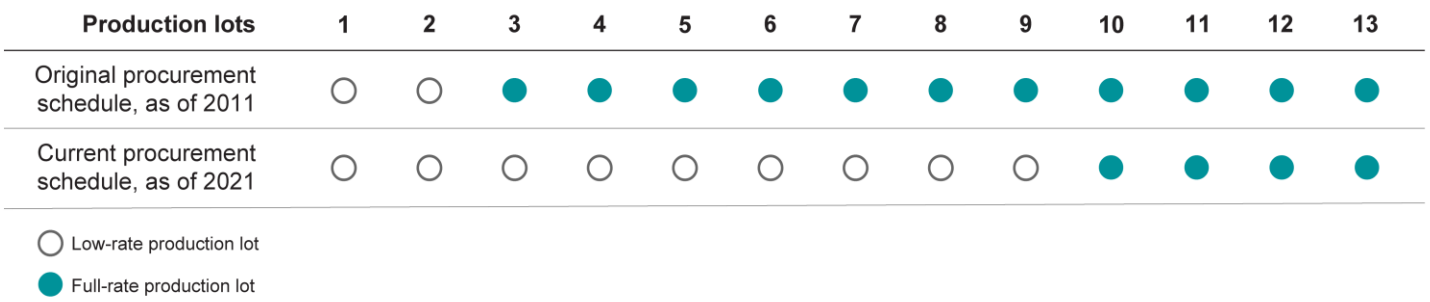
Source: GAO presentation of KC-46 program schedule documentation and information. | GAO-22-104530

The Air Force is continuing to procure aircraft with unresolved RVS and boom deficiencies during an extended low-rate initial production phase of the program, since the full rate production decision has been delayed. To maintain the planned production schedule, more aircraft will be procured under low-rate initial production than under full-rate production. According to DOD policy, proceeding to a full-rate production decision generally requires that the system meets acceptable performance, among other things.[15] In the case of the KC-46, the program's RVS and boom will not have demonstrated acceptable performance prior to fiscal year 2024. In 2016, the Under Secretary of Defense for Acquisition, Technology and Logistics approved the KC-46 program's low-rate initial production decision for the first four lots, for a total of 49 aircraft. Since then, the program has converted additional production lots from full-rate production to low-rate initial production. Under current plans, by the end of fiscal year 2024, the Air Force will have procured at least 118 aircraft through lot 9, or about 67 percent of the 175 production aircraft, before testing on the RVS and boom fixes are complete. According to Air Force officials,

[15]According to DOD policy, proceeding to a full-rate production decision requires control of the manufacturing process, acceptable performance and reliability, the establishment of adequate sustainment and support systems. DOD Instruction 5000.85, Major Capability Acquisition, change 1 (Aug. 6, 2020).

maintaining the planned production schedule allows the Air Force to receive and use delivered aircraft in limited operations until the new boom and RVS are delivered. Figure 5 shows the original and current procurement schedules for low- and full-rate production, by lot.

Figure 5: Original and Current Program Low-Rate and Full-Rate Production Lots



Source: GAO analysis of program information. | GAO-22-104530

KC-46 Acquisition Costs Remain under Initial Estimate but Have Increased by $1 Billion since 2019

Since 2019, the program acquisition cost estimate increased by nearly $1 billion, primarily due to deferring purchases of some aircraft by several years when they will be more expensive, and the costs to redesign and retrofit a new boom. However, as we previously reported in 2019, the program had been on track to deliver aircraft below the original cost estimate, and even with the increase, the total acquisition cost remains lower than the initial estimate of $51.7 billion. Program acquisition costs increased from $43 billion in January 2019, when we last reported on the program, to $44 billion as of December 2020—the program's most recent cost estimate.[16] Table 2 compares the program's acquisition costs for the initial, January 2019, and December 2020 estimates.

[16]GAO-19-480.

Table 2: Total Acquisition Costs Are Approximately $1 Billion More than 2019 Estimate, as of December 2020

	February 2011 initial estimate	January 2019 estimate	December 2020 estimate	Difference from 2019 to 2020
Acquisition cost estimate (then-year dollars in millions)				
Procurement	40,236.0	34,188.7	34,752.6	563.9
Aircraft[a]	25,853.7	16,367.4	17,139.9	772.5
Boom telescope actuator retrofit	-	-	219.2	219.2
Other cost adjustments[b]	-	-	(427.8)	(427.8)
Development	7,149.6	5,857.7	6,037.9	180.2
Boom telescope actuator redesign	-	-	140.0	140.0
Other cost adjustments[a]	-	-	40.2	40.2
Military Construction	4,314.6	2,872.1	3,107.5	235.4
Total acquisition cost (then-year dollars in millions)	**51,700.2**	**42,918.5**	**43,898.0**	**979.5**

Legend: Dashes in February 2011 and January 2019 estimate indicate that those costs were not accounted in those estimates.

Source: GAO analysis of the KC-46 program data. | GAO-22-104530

Note: The December 2020 estimate is the program's most recent cost estimate.

[a]The aircraft buy quantity profile could change pending future appropriation acts. The Air Force received funding in excess of what it anticipated to receive in fiscal year 2021, and plans to purchase an additional aircraft in fiscal year 2022, which could result in adjustments to quantities procured in subsequent years.

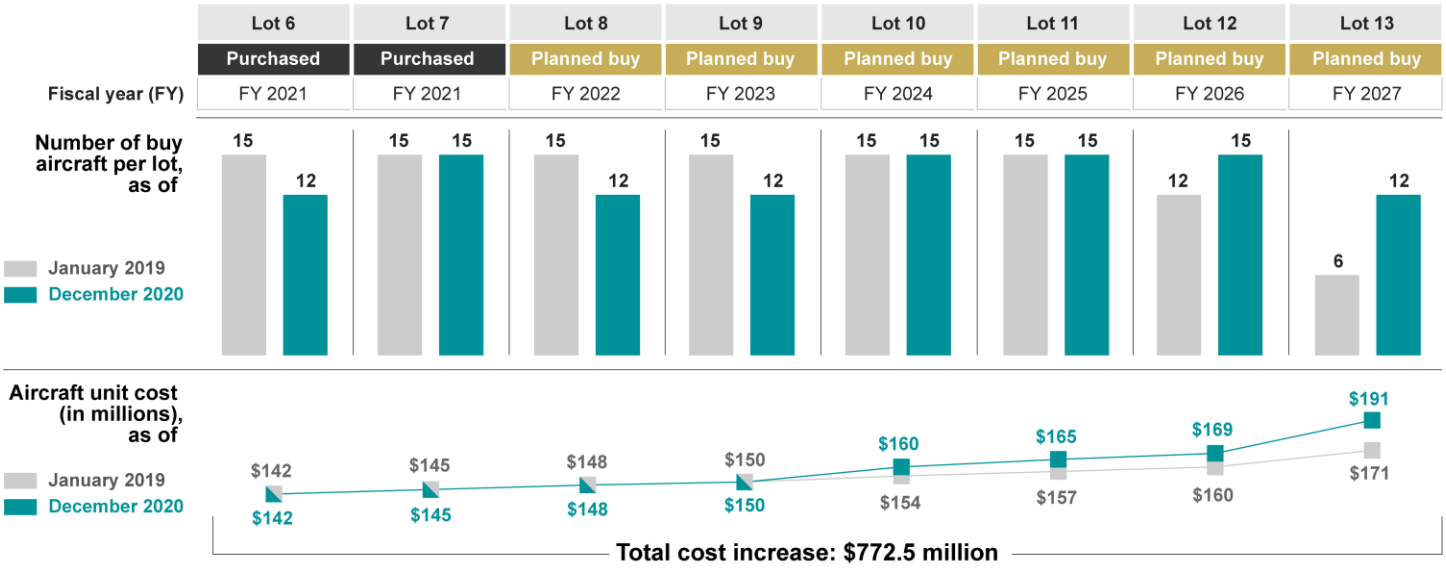
[b]The program's development cost changes from 2019 to 2020 include increases in cost of government testing, take-off and landing data, and the aircrew training system. The program's procurement cost changes from 2019 to 2020 include decreases in the economic price adjustment, estimate for engineering change orders, other statutory and non-statutory adjustments, and fact-of-life changes.

- **Deferment of aircraft procurements.** Since 2019, the Air Force deferred KC-46 aircraft procurements by several years because of delays caused by the critical deficiencies, which added $772.5 million to the program's acquisition costs. Specifically, program officials said the Air Force plans to defer nine near-term aircraft purchases to future years and reprogram some of the associated funding to other priorities because of the program delays resulting from the refueling system deficiencies.[17] The KC-46 contract includes both fixed-prices and not-to-exceed prices for aircraft based on the production lot they are purchased in. Generally speaking, if the government defers purchasing aircraft in earlier lots, but then purchases those aircraft in

[17]In fiscal year 2020, the Air Force reprogrammed $30.4 million of the program's procurement funds to other priorities.

later lots, it increases the per-unit cost of the aircraft purchased in later years. The ultimate financial impacts may differ depending on what is included in future appropriation acts. Figure 5 shows how the program delays have led the Air Force's plans to buy fewer aircraft than initially planned in earlier lots and buy more aircraft in some later lots, increasing the per-unit cost of aircraft purchased in later years.

Figure 6: KC-46 Near-Term Buys Deferred to Later Years and Associated Cost Estimate Increases Based on Enacted Fiscal Year 2021 Budget



Source: GAO analysis of the KC-46 program data. | GAO-22-104530

Note: The aircraft buy quantity profile could change pending future appropriation acts. The Air Force received funding in excess of what it anticipated to receive in fiscal year 2021, and plans to purchase an additional aircraft in fiscal year 2022, which could result in adjustments to quantities procured in subsequent years.

- **Boom redesign and retrofit efforts.** The program's acquisition cost estimate increased $359 million since 2019 to address the critical deficiency related to boom stiffness. As noted above, in September 2020, the Air Force modified its contract with Boeing to include the redesign, build, and test of the new boom, which the program estimates will be $140 million, but has not yet contracted for retrofitting the redesigned boom to existing aircraft.[18] Program officials

[18]The modification has separate line items for the redesign and the build and test. Boeing will perform the design work under a cost-plus-fixed-fee line item and will perform the build and test work under a cost-plus-incentive-fee line item. Final costs for building and testing the new boom will be determined after work is completed.

expect the retrofit to cost an additional $219.2 million based on a set of assumptions, such as retrofitting all aircraft fielded through lot 9. However, the estimate could change depending on the timing to incorporate the new boom into the KC-46 production line.

Air Force Plans to Take Financial Responsibility for New Remote Vision System Design and Risks Future Cost Growth and Schedule Delays

In October 2021, Air Force officials said they plan to assume financial responsibility for the new RVS design without ensuring the program takes key steps to mature the system's critical technologies. In April 2020, at least 2 years after the identification of the critical deficiencies, the Air Force and Boeing signed a memorandum of agreement that settled the path forward to design a new RVS. However, it also stipulated the Air Force would be financially responsible for any further design changes to the RVS after completing the preliminary design review for the system. According to DOD guidance, the preliminary design review ensures that there is technical confidence that the capability need can be satisfied within cost and schedule goals and that risks have been identified and mitigation plans established. This arrangement, effectively, reversed the original terms of the firm-fixed price contract that aimed to hold Boeing fully responsible for delivering a system that would work in any lighting conditions.

An official in the Office of the Assistant Secretary of the Air Force for Acquisition, Technology and Logistics said that this memorandum of agreement was necessary since Boeing and the Air Force were at an impasse as to how they would address the deficiencies and which party would be financially responsible for the cost burden. Air Force leadership maintained that Boeing was required to deliver a system that met the specifications as outlined in the firm-fixed price contract, but according to the official, Boeing did not agree that it should be fully responsible for the costs of developing and fielding a new system. According to the official, the Air Force was willing to take on future cost risk if Boeing would agree to develop the new RVS and resolve the impasse in the near term. In May 2020, the Air Force incorporated the April 2020 memorandum of agreement as a modification to the original contract.

According to the modified contract, Boeing was responsible for providing a briefing to the Air Force prior to entering into the preliminary design review for the RVS. In its May 2021 briefing, Boeing provided its self-assessment of the technology readiness levels (TRL) of the three RVS critical technologies—the visible camera, the long-wave infrared (LWIR) boom camera, and the primary display. A TRL is a measurement of maturity for each critical technology, numbered 1 through 9 from least to

most mature, based on demonstrations of increasing fidelity and complexity. See table 3 for definitions of the TRLs.

Table 3: Technology Readiness Levels (TRL)

TRL	Description	Example
1	Basic principles observed and reported	Paper studies of a technology's basic properties
2	Technology concept and/or application formulated	Analytic studies
3	Analytical and experimental critical function and/or characteristic proof of concept	Components that are not yet integrated or representative
4	Component and/or breadboard validation in laboratory environment	Integration of ad hoc hardware in a laboratory
5	Component and/or breadboard validation in relevant environment	High fidelity laboratory integration of components
6	System/subsystem model or prototype demonstration in a relevant environment	Prototype testing in a high-fidelity laboratory environment or in a simulated operational environment
7	System prototype demonstration in an operational environment	Prototype testing on the planned environment, such as in an aircraft, vehicle or space
8	Actual system completed and qualified through test and demonstration	Developmental test and evaluation of a system in its intended weapon system to determine it meets design specifications
9	Actual system proven through successful mission operations	Using the system under operational mission conditions.

Source: GAO presentation of information from GAO-20-48G. | GAO-22-104530

At least one of the critical technologies of the RVS is immature and program officials raised questions about Boeing's assessment of the other two critical technologies. Generally, major defense acquisition programs are expected to mature critical technologies to at least a TRL 6 before entering into the engineering and manufacturing development phase—the phase of development that precedes production.[19] However, best practices we identified for technology maturation state that critical technologies of the system should demonstrate a TRL of 7 at the preliminary design review, which would be prior to when the Air Force takes financial liability for any design changes.[20]

Boeing assessed the visible camera at a TRL of 5 or 6, the LWIR boom camera at a TRL of 5 or 6, and the primary display at a TRL of 5 at the time the Air Force entered the preliminary design review. This level of immaturity for the primary display, and possibly the visible camera and

[19]10 U.S.C. § 4252 and 10 U.S.C. § 4272.

[20]GAO, *Technology Readiness Assessment Guide*, GAO-20-48G (Washington, D.C.: January 2020).

LWIR boom camera, falls short of what is generally expected when major defense acquisition programs proceed into engineering and manufacturing development. We found all three critical technologies are immature based on best practices we identified. Program officials also said they were not confident in Boeing's assessment of TRLs for the critical technologies and that the TRLs may be overstated. Furthermore, while Boeing outlined some steps to mature the visible camera and primary display, it did not identify any steps for the LWIR boom camera.

The program does not plan to conduct three key practices before assuming financial responsibility of the new RVS design. According to our *Technology Readiness Assessment Guide*, the program should (1) conduct an independent technology readiness assessment (in this case, independent from the contractor), (2) develop a technology maturation plan, and (3) demonstrate that critical technologies meet a TRL of 7—testing of the system in an operational environment—prior to closing its preliminary review.[21] The sooner the program completes these steps, even if after the design review, the better it can mitigate risks of further cost growth and delays stemming from reliance on immature technologies.

- **Technology readiness assessment (TRA).** Program officials said the program does not plan to complete its own TRA of the new RVS or its three critical technologies prior to closing the preliminary design review, even with concerns from program officials that Boeing's assessment of the TRLs may be overstated. Specifically, program officials and engineers noted that Boeing has flown the visible camera and long-wave infrared camera on its King Air—a twin-turboprop aircraft that is considerably smaller than a KC-46—and one KC-46 developmental test aircraft to collect imagery to use for design maturation. However, Boeing has not tested the system or its technologies in their final configuration or evaluated the performance of those critical technologies against system requirements, such as making contact with receiver aircraft. Furthermore, program officials stated that the performance of the visible camera and the long-wave infrared camera has also not been demonstrated during night or twilight conditions, one of the deficiencies of the current system. In addition, while program officials said the primary display has been tested in the laboratory, it has not been incorporated into the aerial refueling operator station or demonstrated in-flight. The program officials and engineers said that without testing and evaluating the

[21]GAO-20-48G.

critical technologies against performance requirements, they cannot be confident in the maturity of the new system.

Our *Technology Readiness Assessment Guide* states an acquisition program should conduct an independent TRA before it closes its preliminary design review.[22] Doing so provides greater assurance that the system will meet key performance requirements and make the transition from the product development phase to the production phase. Conducting a TRA prior to closing the preliminary design review would, therefore, help the Air Force determine the point at which taking financial responsibility of the design is appropriate. Furthermore, without a solid understanding of how mature the critical technologies of the new RVS are prior to the preliminary design review, the program is at greater risk of approving a design that is less likely to remain stable, which could lead to further cost growth or schedule delays. Furthermore, the sooner the program understands the design risks associated with immature technologies, even after the preliminary design review, the better it can identify the steps it needs to take to mature those technologies and mitigate those risks.

- **Technology maturation plan (TMP)**. Program officials said the program has not developed a TMP to mature the three critical technologies of the new RVS. A TMP is developed for critical technologies that do not meet specific TRL goals and require further evaluation, testing, or engineering work to bring the immature technology to the appropriate TRL. Our *Technology Readiness Assessment Guide* states that the program should develop a maturation plan if it has not demonstrated a TRL of 7 for each of the critical technologies prior to preliminary design.[23] Maturing critical technologies to a TRL of 7 provides greater confidence in the overall design and indicates the system's design is more likely to remain stable. The KC-46 program's approach to developing the original RVS underscores the importance of maturing critical technologies to a TRL of 7 because it did not do so then and now has to redesign the whole system.

  Neither Boeing nor the program office developed a TMP for all three of the critical technologies that documents a plan to demonstrate a TRL of 7, and at least one of these critical technologies is considered high risk. The last technology maturation plan Boeing completed was

[22]GAO-20-48G.

[23]GAO-20-48G.

in 2016, prior to the identification of the critical deficiencies, and it has not been updated to address the steps needed to mature critical technologies of the new RVS. In addition, both Boeing and program officials identified the LWIR boom camera as particularly high-risk of not meeting system requirements because the camera cannot differentiate between the boom tip and the receiver areas on certain receiver aircraft. The RVS program manager said that based upon a technical assessment of LWIR technology for refueling applications, the boom camera will not meet requirements for covert boom refueling. In addition, the RVS program manager noted concerns that the LWIR panoramic cameras, though not a critical technology of the new RVS, will not meet requirements to detect and recognize fighter-sized aircraft within required distances absent significant hardware changes. Without a plan outlining a path forward towards maturing the critical technologies before the preliminary design review, the program is at risk of facing additional cost increases to mature the new RVS, as well as encountering delays in developing a solution for refueling covert aircraft.

- **Prototype testing in operational environment.** Program officials said the program does not plan to integrate and test the RVS in an operational environment prior to closing their preliminary design review and taking on financial liability of the design. Our *Technology Readiness Assessment Guide* states that program officials should demonstrate a TRL of 7—testing a prototype of the system, inclusive of the critical technologies, on a KC-46 in an operational environment—prior to the preliminary design review to ensure the system's stability. The program, however, does not plan to test the RVS prototype on the KC-46 until 2023, during developmental testing, meaning it will take another 2 years to determine whether the integrated system works. This increases the chances that the program discovers new deficiencies later than it could have, which is what happened during the development of the original RVS. In March 2014, we found that the program did not test the original RVS in a realistic environment even though the program had entered into system development, and was well past its preliminary and critical design reviews.[24] It was not until developmental in-flight testing activities in 2017 that the Air Force began to discover the critical deficiencies that ultimately led to the need to redesign the system.

[24]GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-14-340SP (Washington, D.C.: Mar. 31, 2014).

Between June and October 2021, we discussed our concerns regarding closing the preliminary design review prior to ensuring the maturity of the RVS with the KC-46 program manager, the RVS program manager, an official from the Office of the Assistant Secretary of the Air Force for Acquisition, Technology and Logistics, and the Secretary of the Air Force. During those discussions, officials recognized the risk of proceeding with closure of the preliminary design review, including taking financial responsibility for the RVS design and any future design changes. In October 2021, program officials said they decided to postpone closure of the review until an unspecified date due to the concerns with the maturity of the new RVS design, including that the LWIR panoramic cameras will not meet requirements. However, even though the program is postponing closure of the preliminary design review, officials told us they do not plan to complete a TRA or TMP for the critical technologies or the panoramic cameras, nor test the full system prototype on a KC-46, prior to closing the review.

Though the modification to the contract does not require the Air Force to conduct a TRA, TMP, and prototype testing of the new RVS, taking these steps prior to closing the preliminary design review, or as soon as possible thereafter, would provide the program with greater insight into the cost and schedule risks it will assume. The program office said its rationale for planning to close the preliminary design review without completing a TRA, TMP, and testing a prototype of the system in an operational environment was twofold. First, the program wanted to use funds available in fiscal year 2021 to pay expenses associated with closure of the review. According to the modified contract, the Air Force is required to pay Boeing $106 million at the closure of the preliminary design review. In September 2021, program officials said the Air Force paid $95 million to Boeing and withheld the remaining $11 million, to maintain leverage until the closure of the review. Second, program officials said their need to quickly field the new RVS for the warfighter makes a formal TRL assessment, TMP, and prototype testing impractical because of the additional time it would take to complete these steps. However, without a comprehensive understanding of the maturity of the critical technologies that would be provided by performing a TRA, ensuring Boeing is taking appropriate steps to mature those technologies through development of a TMP, and ensuring an RVS prototype works in an operational environment, the Air Force risks carrying design issues into RVS production. This could lead to further cost increases and delays in getting a fully capable system to the warfighter. Finally, if the program is unable to complete these steps prior to closing the preliminary design review, taking these steps as soon as possible will help the program

identify and mitigate technical risks associated with the RVS design, potentially avoiding further cost and schedule growth that could result from identifying technologies that are not ready at a later point.

The Air Force Plans to Use Partially Capable KC-46s to Address Temporary Tanker Capacity Reductions and Is Studying Contracted Aerial Refueling

The Air Force plans to use the partially capable KC-46s to meet day-to-day aerial refueling requirements to mitigate near-term tanker capacity reductions, while also studying whether a contracted aerial refueling program is viable to meet future training requirements. The Air Force is projecting a temporary reduction in tanker capacity over the next few years due to the delays caused by the KC-46's RVS and boom deficiencies, as well as plans to retire KC-10 and KC-135 tankers. To address this tanker capacity reduction, the Air Force's Air Mobility Command (AMC) is developing a plan to expand the use of KC-46 tankers, even though the critical deficiencies are not resolved, so it can retire some legacy aircraft. The Air Force is also studying the feasibility of a contracted aerial refueling program, which it plans to complete in 2023.

The Air Force's Fleet of KC-10 and KC-135 Tankers Is Expected to Decline Due to Scheduled Retirements

The Air Force's KC-10s and KC-135s retirement schedule has resulted in a reduction in the number of legacy refueling tankers, as compared to recent years. In fiscal year 2021, the Air Force had a total of 442 legacy tankers, comprised entirely of KC-10s and KC-135s. That number is expected to decrease by almost 15 percent, to 376 legacy tankers, by the end of fiscal year 2024 as aircraft are retired. This reduction is expected to occur before Boeing is scheduled to start retrofitting delivered KC-46s with the new RVS and boom in 2024 and 2025, respectively. The National Defense Authorization Act for 2021 prevented the Air Force from retiring as many legacy tankers as planned. At the time, USTRANSCOM had expressed concerns regarding a gap in meeting aerial refueling demand. The law included language that prohibited the Air Force from retiring any additional KC-135s and to maintain at least 26 KC-10s through fiscal year 2023.[25] However, the National Defense Authorization Act for Fiscal Year 2022 included provisions that reduced—but did not eliminate—restrictions on the Air Force to retire its legacy air refueling tankers.[26] The provisions remove all retirement restrictions for the KC-10 and allows the Air Force to retire up to 18 KC-135s through fiscal year 2023.[27] Figure 7 shows the

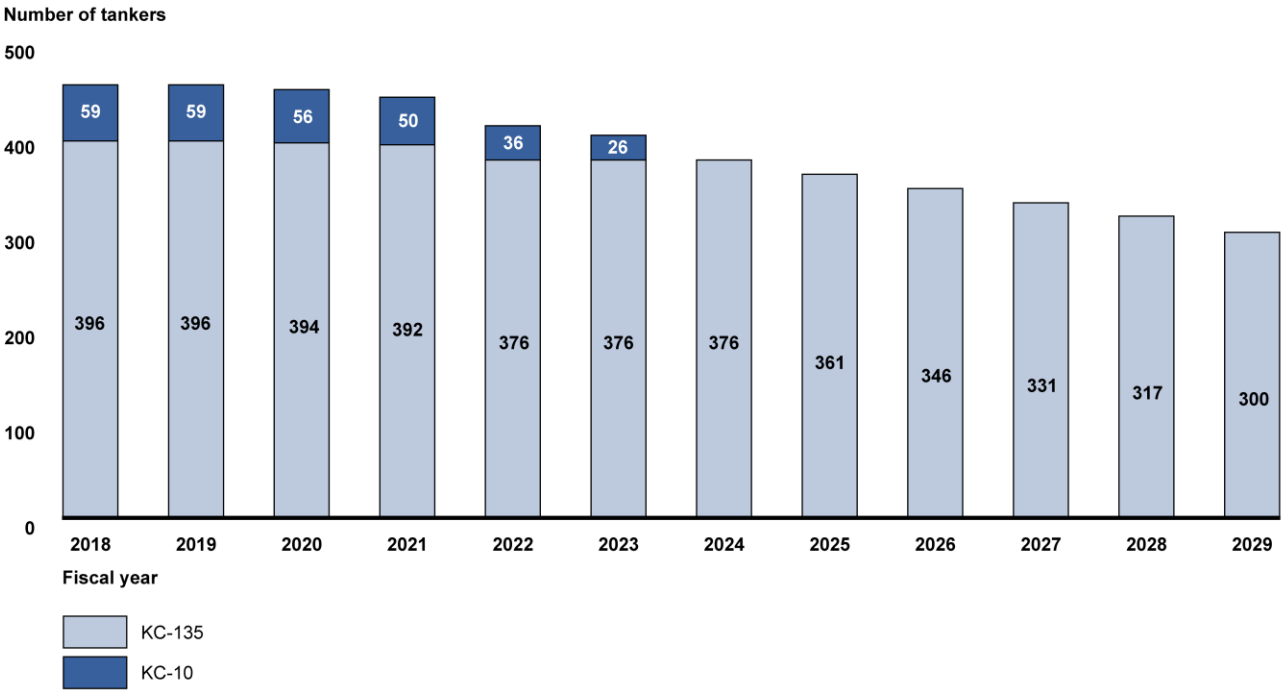
[25]This prohibition is subject to several exceptions.

[26]Pub. L. No. 117-81, § 137 (2021).

[27]This general prohibition of KC-135 retirements is subject to several exceptions.

total actual and planned number of KC-10s and KC-135s in the Air Force from fiscal years 2018 through 2029.

Figure 7: Actual and Planned Number of KC-10 and KC-135 Tankers in the Air Force



Source: GAO analysis of Air Mobility Command and KC-46 information. | GAO-22-104530

Note: Fiscal years 2018 through 2021 reflect actual number of legacy tankers in the Air Force, and fiscal years 2022 through 2029 reflect planned number of legacy tankers. The legacy tanker retirement schedule is based on provisions in the National Defense Authorization Acts for Fiscal Years 2021 and 2022 that limits the number of tankers the Air Force can retire. The total number of KC-135s and KC-10s for each fiscal year includes those operated by active duty crews as well as those by the Air National Guard and Air Force Reserve Command. The legacy tanker retirement schedule is notional pending actual KC-46 deliveries.

AMC Plans to Mitigate Aerial Refueling Capacity Shortfall by Expanding the Use of Partially Capable KC-46s

To maintain its required tanker fleet size and mitigate the planned retirements of the KC-10s and KC-135s, the Air Force plans to use KC-46s in limited operations until the delivered KC-46s are retrofitted with the new RVS and boom. Based on a USTRANSCOM study and statutory requirement, the Air Force is required to maintain a fleet size of 479

tankers to meet its wartime requirement.[28] According to Air Force officials, they count all KC-46s, including those delivered prior to being fully operational, toward the wartime fleet size threshold. Air Force officials indicated that if KC-46 deliveries fall further behind schedule, the Air Force would make adjustments to the retirement schedule to ensure that they meet the statutory fleet size requirement throughout the period.

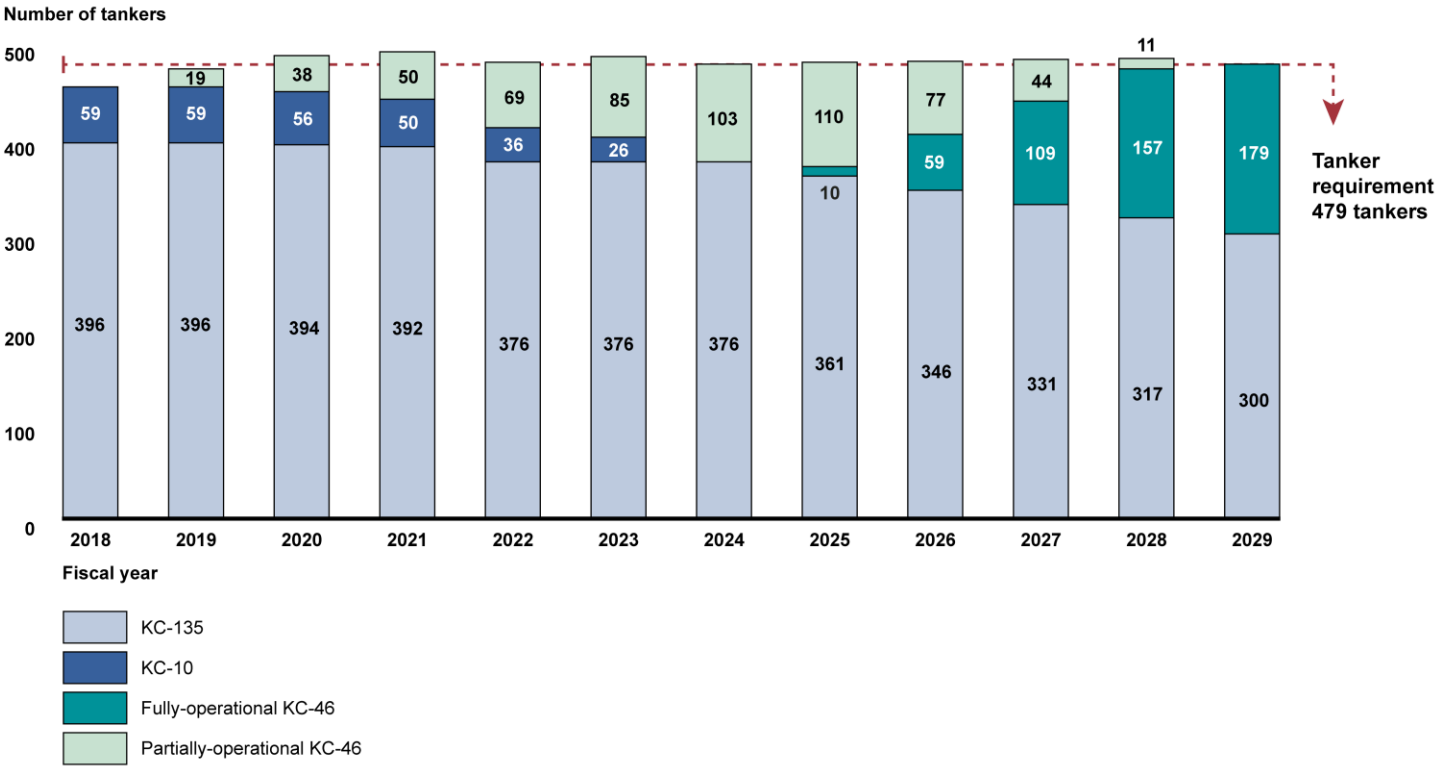
Air Force officials acknowledged that they are facing a reduction in tanker capacity to meet day-to-day aerial refueling requirements as a result of the KC-46 delays and scheduled tanker retirements, but noted that KC-46 aircraft are already in use. Because of the limitations of the KC-46 operational functionality—primarily due to the deficiencies with the RVS and boom—the Air Force has only used KC-46s to refuel aircraft under certain conditions. For example, it can conduct hose-and-drogue refueling, but is limited in terms of conducting certain boom refueling activities due to issues with the boom stiffness with smaller receiver aircraft, like the A-10. These limits are also due to the challenges with the RVS system that limit boom refueling under certain lighting conditions. In addition, AMC has not cleared KC-46s to conduct operational combat deployments. However, the Air Force has been operating KC-46s for training aerial refueling crews. For example, according to AMC officials, KC-46s flew 6,654 sorties and offloaded over 37.8 million pounds of fuel to receiver aircraft, through 28,000 boom and 1,900 hose-and-drogue contacts from January 2019—when the first KC-46 was delivered to the Air Force—through November 16, 2021.

As part of AMC's plan to meet aerial refueling requirements, it identified a series of interim capability releases (ICR) that would reduce use restrictions as a result of the RVS and boom deficiencies and allow KC-46s to incrementally meet more demand with the current configuration until they reach full operational capability. For example, an AMC official said that they approved the KC-46s for hose-and-drogue refueling in July 2021. In August 2021, AMC allowed for missions using the boom to refuel

[28]National Defense Authorization Act for Fiscal Year 2019, Pub. L. No. 115-232, § 141(a) (2018); USTRANSCOM Mobility Capabilities and Requirements Study 2018. The Fiscal Year 2019 National Defense Authorization Act directed the Air Force to maintain a total aerial refueling tanker inventory of 479 aircraft; however, the act provides procedures through which the Secretary of the Air Force can reduce the inventory. The inventory size is based on the Mobility Capabilities and Requirements Study 2018 determination that an estimated fleet size of 479 was necessary to meet combatant commander mobility requirements consistent with the 2018 National Defense Strategy strategic environment, wartime missions, and simultaneity guidance. USTRANSCOM issued a more recent Mobility Capability and Requirements Study in 2021 (classified).

C-17s, B-52s, and other KC-46s. AMC issued a memo in October 2021 announcing it had approved the expansion of KC-46 boom aerial refueling to F-15s and F-16s. Furthermore, in December 2021, AMC expanded boom refueling to additional aircraft, including the AC/HC/MC-130J, C-5, and E-3G. Air Force officials stated the ICR plan will allow the KC-46s to provide a significant contribution toward meeting domestic day-to-day aerial refueling demand, while allowing the current fleet of fully operational tankers to meet the requirements for overseas combatant command deployments in hostile areas. Figure 8 shows the total actual and planned tanker fleet size, including the partially-operational KC-46s, from fiscal years 2018 through 2029.

Figure 8: Actual and Planned Aerial Refueling Tanker Fleet Size in the Air Force



Source: GAO analysis of Air Mobility Command and KC-46 information. | GAO-22-104530

Notes: Fiscal years 2018 through 2021 reflect actual number of legacy tankers in the Air Force, and fiscal years 2022 through 2029 reflect planned number of legacy tankers. The estimated schedule for the Air Force to acquire fully operational KC-46 tankers is based on the KC-46 program estimates for the retrofit and production fold-in schedule for the redesigned boom, which is expected to start July 2025. Program officials noted that the actual retrofit schedule could change based on many factors including funding, parts availability, and aircraft availability.

The legacy tanker retirement schedule is based on provisions in the National Defense Authorization Acts for Fiscal Years 2021 and 2022 that limit the number of tankers the Air Force can retire. The legacy tanker retirement schedule is notional pending actual KC-46 deliveries.

The total number of fully operational aerial refueling tankers each fiscal year includes those operated by active duty crews as well as those by the Air National Guard and Air Force Reserve.

According to AMC officials, the primary challenge to meeting day-to-day aerial refueling capacity requirements is ensuring there are enough available and trained aerial refueling crews, not necessarily the number of tankers in the fleet. The day-to-day aerial refueling requirements are different from the required fleet size of 479 that USTRANSCOM determined is necessary to meet estimated wartime requirements. According to AMC officials, the Air Force needs to maintain trained crews and tankers to operate approximately 90 tankers a day that are available at any given time to meet ongoing day-to-day aerial refueling requirements. These crews include those on active duty as well as those from the Air National Guard and Air Force Reserves. The day-to-day demand for aerial refueling includes various types of missions, including support for combat and non-combat missions such as support for large-scale training exercises, aerial refueling support for pilots conducting training at home station locations, test and evaluation support, and support for transporting aircraft overseas.

The Air Force's Studies, Analysis, and Assessments directorate developed two analysis tools to project future aerial refueling demands and capacity and to support the determination that the ICR plan will ensure that AMC can meet day-to-day aerial refueling demands until the KC-46s are fully operational. The directorate forecasted:

- aerial refueling demand by using data on using historical aerial refueling support for military operations, training, and other missions; forecasted deployments; and the amount of training requirements necessary for existing and future pilots,[29] and
- aerial refueling capacity by using data on the planned schedule of tanker retirements, the estimated delivery and ICRs for the KC-46, and the estimated availability of trained aerial refueling crews from both active duty and the air reserve components.

Air Force Studies, Analysis, and Assessments directorate officials said that their assessment forecasts that the ICR plan can meet aerial

[29]We reviewed the analyses and spoke with Air Force officials who developed and populated these models, but we did not independently verify the reliability of the data nor the results of the analyses.

refueling requirements until all KC-46s are fully operational in fiscal year 2029. According to the officials, one of the primary factors that allows the ICR plan to succeed in meeting day-to-day aerial refueling requirements is the current and continued estimated reduction in demand to support overseas military operations. Air Force officials estimate it will continue further reductions due to fewer requirements to support areas such as Afghanistan. For example, total operational flying hours for aerial refueling tankers from fiscal year 2015 to fiscal year 2020 decreased from 269,507 to 170,845—a reduction of 37 percent.[30]

According to AMC officials, the ICR plan also supports the updated legacy tanker retirement schedule, as shown in figure 7 above and reflects reduced retirement restrictions, so tanker crews can transition to supporting KC-46 operations. AMC officials said that absent the ICR plan, they would transition and train KC-46 crews later and would therefore slow down deployment of the KC-46 tankers. Air Force officials stated that accelerating the retirements would allow for a smoother transition as more crews become available to operate KC-46s and would enable the Air Force to maintain aerial refueling capacity. In addition, AMC officials said that the ICR analysis indicates that additional delays of the new boom and RVS will not significantly affect their ability to meet day-to-day aerial refueling requirements. This is because such delays will not prevent the Air Force from using the KC-46, as long as a sufficient number of crews from the legacy tankers are retrained for the KC-46.

While AMC says that the ICR plan addresses estimated day-to-day aerial refueling requirements, it does not necessarily mean that it knows if the Air Force is meeting all aerial refueling demand. In the past, Air Force and TRANSCOM officials stated there was unmet demand for aerial refueling. However, the Air Force has not verified that there was unmet demand with operational data, nor has there been a determination of the effects any unmet demand has had on overall requirements and operations. For example:

- In an April 2020 report to Congress, the Air Force and USTRANSCOM reported that as many as 30,000 hours of aerial refueling missions are not supported annually. In 2019, AMC reported to industry representatives that there was a 20,000 to 30,000 annual

[30]Air Force Readiness Generation Branch. The data represent total funded operational and maintenance flying hours for aerial refueling tankers by Air Force Major Commands based on end-of-year flying hour reports. These totals do not include flying hours identified under different funding categories or programs.

hourly gap in aerial refueling support. AMC and Air Force officials were unable to provide any data to us during the course of our work to substantiate these claims.

- Also in its April 2020 report to Congress, the Air Force stated that a survey of its Major Commands found that only half of the requests for aerial refueling support for training operations were fulfilled.[31] However, the Air Force did not go on to determine the effect on unit readiness or operations as a result of this unmet demand.

AMC officials stated that a new aerial refueling request database is expected to provide better insight into potential demand versus formal aerial refueling requirements. According to the officials, the ICR plan will allow AMC to meet formal aerial refueling requirements, though it may not always be able to support the number of tankers requested or the informal requests made. AMC officials said that in some instances, units requesting tanker support from AMC may have elected to informally contact AMC officials to inquire if a request could be met, but elected to not formally request refueling support if AMC officials told them that tankers were not available on the day in question. Other requests, such as those to provide local training support, were often arranged without AMC support. For example, requesting units may go directly to the Air National Guard to request support. AMC officials noted that there is an "insatiable" demand for aerial refueling support, in part, because pilots want to fly as much as possible.

To better ensure all aerial refueling requests and support are captured in one database, AMC has implemented a new software system—Magellan—that centralizes and tracks aerial refueling requests as well as scheduling and allocation information. AMC officials said that data from Magellan can be used to more accurately estimate short-term aerial refueling demand. While it is too early to assess the efficacy of using Magellan to track aerial refueling demand, AMC plans to assess whether there is unmet aerial refueling demand as part of its ongoing efforts to study the feasibility, affordability, and advisability of contracted aerial refueling.

[31]Department of the Air Force, Report to Congressional Committees. CRR-FY20 Contractor-Operated Aerial Refueling Aircraft. April 2020

AMC Is Studying the Expansion of Contracted Aerial Refueling

In response to direction from a report accompanying the National Defense Authorization Act for Fiscal Year 2020, AMC—on behalf of the Secretary of the Air Force—developed a plan to study the feasibility, affordability, and advisability for the Air Force to contract commercial aerial refueling services to meet any gaps between aerial refueling capacity and requirements.[32] The final report is expected to be completed in 2023 and will support a determination as to whether the Air Force should move forward with a contracted aerial refueling services program. The Navy has operated its own contracted aerial refueling service program to meet its training needs since 2001. For more information about the Navy's contracted aerial refueling service, see appendix II. Similar to the Navy's program, an Air Force contracted aerial refueling program would not participate in combat operations, but would support day-to-day aerial refueling requirements such as training support, test and evaluation, and transporting aircraft overseas. According to AMC officials, they would expect training support to represent the type of missions that would receive the most support from contractors. Unlike the Navy, which primarily uses the hose-and-drogue refueling method, Air Force aerial refueling contractors would provide the more complex boom refueling capability.

The Air Force's ongoing commercial aerial refueling study represents the most recent in a series of efforts by the Air Force since 2008—such as another contracted aerial refueling study, industry days, and a pilot program—to explore the option of contracting for aerial refueling services.

Commercial aerial refueling study. AMC developed the scope and approach of the study plan, which the Secretary of the Air Force approved in May 2021. AMC expects the final report to be completed in mid-2023 at the earliest. According to the plan, the study will first identify and assess whether there is an aerial refueling day-to-day capacity gap and the extent of such a gap. The plan requires the study to then identify and assess various options to meet any identified aerial refueling capacity gap, including options that rely on both contractor- and government-provided aerial refueling. The study will also include a full business case analysis for contracting for aerial refueling services. According to the study plan, the study will assess nine different approaches from three models:

[32]H.R. Rpt. 116-120, at 94-95 (June 19, 2019)

- government-owned/contractor-operated solutions, such as using private crews operating aircraft owned by the government,
- contractor-owned/contractor-operated solutions, such as using private crews operating aircraft leased by the Air Force, and
- government-owned/government-operated solutions, such as using active duty and reserve crews with aircraft from the Air Force's aerial refueling fleet.

For each option, the study is to include an assessment of multiple factors, including the estimated cost and schedule, regulatory and legal challenges, and security implications. An AMC official noted that the cost analyses for the study will likely take the most time and effort due in part to the lack of comparable data for contracted and military-provided aerial refueling service. The study will leverage information from a June 2021 USTRANSCOM Mobility Capability Requirements Study about aerial refueling capacity and demand.

The forthcoming commercial aerial refueling study is the second report to originate from the 2019 House Report directing the Air Force to look at the private sector as a source for aerial refueling. The Air Force previously reported on the potential use of contracted support in April 2020. That report stated that the Air Force needed a more in-depth analysis to make any contracting decisions. It did not include a determination or estimate of any aerial refueling capacity gap. The Air Force agreed to submit the plan for the follow-up study, which the Secretary of the Air Force approved in May 2021. An AMC official explained that designing such a complex study plan took longer than anticipated. Once the study is completed, it could take additional time for the Air Force to award its own contract, and for the contractors to obtain tankers and get the requisite certifications.

Industry day and requests for information. Prior to the April 2020 report, AMC and USTRANSCOM held an industry day and submitted requests for information in 2018 and 2019 to gauge industry interest and capability in providing aerial refueling services. They also sought to obtain information about costs and challenges from potential providers. Several potential aerial refueling service providers attended at least one of the two industry days and many described barriers to starting a contracting program, including:

- Most respondents did not have aircraft that could be equipped for aerial refueling capability and would need to acquire aircraft once they were awarded a contract. Some of the options that respondents

presented included: directly purchasing new tankers, purchasing used aircraft from foreign armed services, and leasing refueling-capable aircraft.

- There were potential challenges associated with acquiring Federal Aviation Administration certifications and complying with federal acquisition regulations.
- Some respondents also cited the additional challenge of developing boom capability.
- Nearly all respondents noted that they would need to ensure the award was sufficient to cover the high capital investment associated with acquiring and maintaining capable aircraft, such as awarding long-term contracts at a length of 5-10 years at a minimum number of flight hours.

2008 contracted aerial refueling pilot program. The National Defense Authorization Act for Fiscal Year 2008 directed the Air Force to initiate a pilot program to assess the feasibility and advisability of utilizing commercial fee-for-service aerial refueling tanker aircraft for Air Force operations. The Air Force's study for the program, issued in August 2009, estimated that increasing the use of the Air National Guard and investing in its own tanker fleet would provide additional aerial refueling hours at less cost than the contracted aerial refueling pilot program. The Air National Guard and Air Force Reserve volunteered to provide an equivalent capacity of the pilot program and the Air Force did not complete the program.

Conclusions

The availability of KC-46 aircraft that meet the requirements set out for them is critical for Air Force to meet the needs of the warfighter. While the warfighter is using the KC-46, it is partially capable, and any further delays will limit how the aircraft can be used. Choosing to relieve Boeing of its financial responsibility to fix RVS after the preliminary design review makes it more important for the Air Force to evaluate the risks of the RVS design before committing to it. Absent doing this prior to completing the review, the Air Force would still benefit from taking these steps as soon as possible thereafter to mitigate the risk of further cost growth and delays in delivering promised capability to the warfighter. The KC-46 program plans to commit to an immature design for the replacement of the RVS without developing its own technology readiness assessment and a technology maturation plan for the critical technologies. Further, the program does not plan to conduct in-flight testing of an integrated RVS prototype prior to completing the design, which could result in the Air Force uncovering new issues later. These choices mirror those made

during the development of the KC-46 that led to the delivery of an aircraft that did not fully meet its requirements, and the Air Force stands poised to potentially repeat its past mistake. Without taking these steps, either before or after the preliminary design review, the program risks additional design changes that could result in cost growth and further schedule slips for the program. The earlier the program takes these steps to understand any technical risks, the better prepared the program will be to address those risks.

Recommendations for Executive Action

We are making three recommendations to the Air Force:

The Secretary of the Air Force should direct KC-46 program officials to complete an independent TRA of the redesigned remote vision system's critical technologies prior to closing the preliminary design review or as soon as possible thereafter, to ensure a comprehensive understanding of the maturity of the critical technologies. (Recommendation 1)

The Secretary of the Air Force should direct KC-46 program officials, in coordination with Boeing and prior to closing the preliminary design review or as soon as possible thereafter, to develop TMPs for the remote vision system's critical technologies. (Recommendation 2)

The Secretary of the Air Force should direct KC-46 program officials to test a full prototype of the remote vision system on a KC-46 in an operational environment prior to closing the preliminary design review or as soon as possible thereafter. (Recommendation 3)

Agency Comments and Our Evaluation

We provided a draft of this report to DOD for review and comment. The Air Force provided written comments, which we reproduced in appendix III. The Air Force also provided technical comments, which we incorporated as appropriate. In its written comments, the Air Force did not concur with our three recommendations, and provided overall comments and its rationale for disagreeing with each recommendation. We stand by our three recommendations.

In its overall comments, presented at the end of its letter, the Air Force stated that the RVS design maturation is on track and that our report implies the new RVS will not work. However, the Air Force also acknowledged that the new RVS design does not currently meet one contractual requirement, which could present KC-46 refueling limitations in covert operations. Further, throughout its comments, the Air Force states that its 2020 memorandum of agreement with Boeing established framework to deliver an improved RVS on an accelerated timeline. While

the memorandum does not require these steps, it does not preclude the Air Force from taking these measures to reduce its own future cost and schedule risks, which it has chosen to take on by entering into the memorandum of agreement.

The Air Force did not concur with the first recommendation to complete an independent TRA of the new RVS critical technologies prior to closing the preliminary design review, or as soon as possible thereafter. In its comments, the Air Force stated that the program and the contractor, aided by industry experts, worked closely to develop a best practical design and noted that it is using a risk management process coupled with efforts to monitor technical performance. The Air Force stated that, given these steps, (1) it is unlikely that a TRA would identify any new risks, and (2) a TRA would require between 6 and 12 months to accomplish, which would lead to schedule growth.

We stand by our first recommendation. We understand that the Air Force is attempting to deliver the capability to the warfighter quickly and that it has taken steps to do so, through the contractor's risk management process. However, the Air Force is relying on the contractor's own assessment of the critical technologies. As we stated in the report, KC-46 program officials acknowledged that the contractor's assessment may be overstated because it has not independently evaluated and vetted the maturity of the three critical technologies of the new RVS. The program has already witnessed several years of schedule growth for reasons including unrecognized technical immaturity of the original RVS. This situation was not discovered until flight tests, and after the preliminary and critical design reviews. Therefore, by choosing to not conduct a TRA on the new RVS to independently assess the maturity of those critical technologies, the program has again exposed itself to further schedule growth if technical risks are identified later in the development cycle. Furthermore, as noted in the report, by signing the memorandum of agreement, the Air Force, not the contractor, will now be responsible for the development costs associated with any unidentified technical risks.

The Air Force did not concur with the second recommendation to develop a TMP for the new RVS critical technologies prior to closing the preliminary design review, or as soon as possible thereafter. In its comments, the Air Force reiterated that the program is using a risk management process, in lieu of developing a TMP, because the program is attempting to deliver the new RVS to the warfighter more quickly. The Air Force states that it has a process to identify risks to the system, mature the technology, reduce risks, and reach performance objectives.

The Air Force also states that developing a TMP would take additional resources, add schedule risk, and duplicate ongoing efforts.

We stand by our second recommendation. We acknowledge that the Air Force chose to use a risk management process, in lieu of developing a TMP, as its plan to mature the new RVS system. However, the plan acknowledges that the LWIR boom camera—a critical technology for achieving the requirements related to covert operations—remains at a high risk of not meeting performance requirements. The plan, as of December 2021, does not specifically address ensuring critical technologies are mature prior to closing PDR or detail when those technologies will be mature afterward. Furthermore, the plan does not address the LWIR panoramic cameras, although not a critical technology, even though the RVS program manager said they will not meet requirements to detect and recognize fighter-sized aircraft within required distances absent significant hardware changes. Program officials acknowledged that existing risk mitigation efforts, primarily software improvements, may not fully address known concerns and that a new LWIR camera may be needed. Without developing a TMP that outlines the steps to sufficiently mature the RVS critical technologies prior to closing the PDR, the Air Force is choosing to take on unknown levels of costs for any future hardware changes associated with the LWIR cameras. Not conducting a TMP also means the Air Force is also taking on any additional schedule delays that may come about from efforts to address those changes.

The Air Force did not concur with the third recommendation to test a full prototype of the new RVS on a KC-46 prior to closing the preliminary design review, or as soon as possible thereafter. In its comments, the Air Force states that testing a full prototype of the new RVS is not practical because the system is highly integrated. The Air Force states that testing an integrated prototype would delay the program approximately 18 to 24 months and significantly delay fielding of the system to the warfighter. The Air Force states that prototypes of the cameras have flown, and that the display has been evaluated in the laboratory.

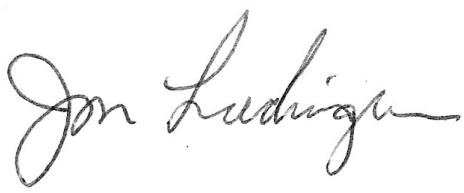
We stand by our third recommendation. We agree with the Air Force's comment that the RVS is a highly-integrated design, which makes it all the more important to test the fully integrated system on a KC-46 since all the technologies have to work together as planned for the entire system to operate effectively. The importance of testing an integrated prototype has been demonstrated through the history of the program. The original RVS design was found deficient only after conducting in-flight testing of

the integrated system beginning in 2017, many years after the program's preliminary and critical design reviews. The Air Force claims it does not have time to test a prototype, but the KC-46 is already 7 years behind schedule due to the flaws with the original design. In addition, the Air Force is already using the KC-46 with the deficient design in instances it has determined it is safe to do so. Furthermore, as noted in the report, AMC acknowledged it can still meet air refueling requirements if the new RVS is delayed past its current projections. If the program proceeds with the current design without testing an integrated prototype of the new design, it will be at risk of repeating the same mistake and discovering additional issues with its technologies late in development; this time with the Air Force bearing the full cost of developing another alternate solution.

Overall, the Air Force's decision to substitute the contractor's risk management process at the expense of following leading practices for technology maturation is concerning given the history of the program. We understand that multi-year delays in delivering the RVS capability have placed the Air Force, and the broader DOD, in need of operational aircraft to meet mission needs. However, the urgent need for a fully capable KC-46 makes it all the more important to take steps demonstrated to reduce the risk of failure.

We are sending copies of this report to the appropriate congressional committees and the Secretary of Defense, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov.

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



Jon Ludwigson
Director, Contracting and National Security Acquisitions

List of Addressees

The Honorable Margaret Wood Hassan
Chair
Subcommittee on Emerging Threats and Spending Oversight
Committee on Homeland Security and Governmental Affairs
United States Senate

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

The Honorable James Lankford
United States Senate

The Honorable Jeanne Shaheen
United States Senate

Appendix I: Objectives, Scope and Methodology

This report assesses the extent to which (1) the Air Force and Boeing have taken steps to address critical deficiencies and meet cost and schedule goals; (2) the Air Force completed a technology readiness assessment (TRA) and technology maturation plan (TMP) for critical technologies in the aerial refueling system; and (3) Air Mobility Command (AMC) has identified aerial refueling capacity gaps due to delays in KC-46, and the actions the Department of Defense (DOD) has taken to address any potential gaps, including the use of contracted services.

To assess the extent to which the Air Force and Boeing have taken steps to address the KC-46's critical deficiencies and meet cost and schedule goals, we obtained and reviewed KC-46 program documents, such as the acquisition program baseline, the contract and modifications, test and evaluation documents, and critical deficiency reports that included information on critical deficiencies. We interviewed officials from the KC-46 program office and the Offices of the Director of Operational Test and Evaluation and the Director of Developmental Test and Evaluation to obtain information on the status of these deficiencies and their observations. We also interviewed representatives from the Boeing Company to obtain insight on their progress toward addressing each of the deficiencies.

For cost and schedule, we reviewed program documents such as defense acquisition executive summary reports, selected acquisition reports, and program briefings. To assess progress toward achieving schedule goals, we compared current schedule estimates to those established at the start of development and how the critical deficiencies affected these estimates. To assess progress toward achieving cost estimates, we compared the December 2020 estimate—the program's most recent estimate—to the initial estimate and to estimates contained in our June 2019 report.

To assess the extent to which the Air Force completed a TRA and TMP for the critical technologies of the aerial refueling system, we focused on the maturity of the remote vision system and interviewed officials from the KC-46 program office including remote vision system subject matter experts, as well as officials in the Offices of the Director of Operational Test and Evaluation and the Director of Developmental Test and Evaluation. We reviewed documentation for the remote vision system's design review, and compared the content to preliminary design review criteria in the KC-46 contract and modifications. We also compared the documentation and information from the program against best practices we identified for developing TRAs and TMPs. Furthermore, we discussed our concerns regarding the program's plan to close the preliminary design

review of the remote vision system without ensuring critical technologies are mature with an official from the Office of the Assistant Secretary of the Air Force for Acquisition, Technology and Logistics, as well as the Secretary of the Air Force.

To assess the extent to which AMC has identified aerial refueling capacity gaps due to delays in KC-46, and what actions AMC has taken to address any potential gaps, we interviewed officials from the United States Transportation Command (USTRANSCOM), the Office of the Secretary of the Air Force, AMC, the Air Force's Legacy Tanker Division, and the Air Force Offices of: Operations, Plans, and Requirements; Strategy, Integration, and Requirements, Plans and Programs; and Studies, Analysis, and Assessments. Documents we reviewed include legacy tanker program documents and retirement schedules, summaries of total tanker flying hours, KC-46 tanker estimated delivery schedules, and training requirement documents.

To identify Air Force and USTRANSCOM plans to address the potential aerial refueling capacity gap, we interviewed officials at the Air Force Office of Studies Analysis and Assessment and reviewed documents related to the Air Force models and analyses developed to determine current and estimated Air Force aerial refueling capacity and demand. To identify the Air Force's plans to determine the need to develop a contracted aerial refueling program, we reviewed AMC's May 2021 Commercial Air Refueling Study Plan. We also reviewed industry responses to 2018 and 2019 USTRANSCOM requests for Information related to contracted aerial refueling services. We did not review the Navy organic aerial refueling capability, but did review the history of Navy's contracted aerial refueling program.

To review the Navy's contracted aerial refueling program, we reviewed aerial refueling services contracts awarded to Omega Air Refueling Services (Omega)—the sole vendor for these services—from 2013 through 2021, and analyzed Navy contract expenditure data of those contracts. Our reporting on the contract expenditures was limited due to the proprietary nature of the contracts. We interviewed officials from the Naval Air Systems Command and Omega representatives to discuss our observations of the contract data. We also reviewed documents for the Navy's Contracted Air Services database, assessed responses from Navy officials to questions about the data system, and sent the results of our analysis to the Navy and Omega for confirmation. We determined that the data were sufficiently reliable for this review. To determine the cost of aerial refueling service provided by the government, we reviewed the

Department of Defense Fixed Wing Reimbursement Rates and interviewed officials at the Office of the Undersecretary of Defense (Comptroller) and contacted the Air Force Cost Analysis Agency. We determined that there was a lack of comparable data sets that prevented us from comparing the cost of aerial refueling services from a contractor versus the government.

We conducted this performance audit from September 2020 to January 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: The Navy's Contracted Aerial Refueling Service Program

The Department of the Navy (DON) is the only Department of Defense (DOD) component that uses a commercial provider for aerial refueling services. The DON includes the U.S. Navy and U.S. Marine Corps. In 2001, the DOD directed the U.S. Navy to start a pilot program for contracted aerial refueling to support the DON's aerial refueling requirements. The DON has relied on a single commercial provider—Omega Air Refueling Services (Omega) since that time. The DON established the contracted aerial refueling service program to improve the availability of tankers when they were requested and reduce reliance on the Air Force's fleet.

Historical Contracted Aerial Refueling Operations and Costs

The DON's contracted aerial refueling program—administered by the Naval Air Systems Command (NAVAIR) Contracted Air Services—supports DON efforts to meet day-to-day aerial refueling requirements. The contracted aerial refueling missions include training support, administrative transportation of aircraft, and testing and evaluation. According to NAVAIR officials, the contracted aerial refueling program does not support combat operations, but provides a significant portion of the DON's aerial refueling service to support training.

Omega has two types of tankers that have historically provided aerial refueling to the DON: the Boeing KC-707A and the KDC-10. Omega has historically provided only hose-and-drogue aerial refueling service because nearly all DON aircraft accept fuel in that manner.

The amount of the DON aerial refueling support provided through contracts and associated costs rates has been generally increasing in recent years. Omega provided over 1,700 total flight hours in fiscal year 2014 and over 2,400 in aerial refueling support in fiscal year 2020. Since fiscal year 2014, the DON has spent approximately $213.5 million in total for contracted aerial refueling services, with costs generally increasing throughout that period. For example, since the start of fiscal year 2014, the costs of contracted aerial refueling services has increased by 81 percent, as of September 20, 2021.[1] NAVAIR officials noted that contracted aerial refueling rates are sensitive to the amount of required flight hours due to high fixed costs associated with acquiring and maintaining aircraft. They also noted that a general increase in annual

[1]To compare contracted aerial refueling cost rates, we determined the fully burdened cost rates for each contract delivery period by combining total expenditures and dividing by the amount of billed flight hours. The delivery periods were identified in the two aerial refueling contracts covering the period from September 27, 2013 through September 20, 2021.

flight hours for aerial refueling providers results in an overall decrease in aerial refueling costs per flight hour.

New Competitive Award for Future Contracted Aerial Refueling Services

In July 2021, NAVAIR awarded the DON's first aerial refueling service contract to another contractor besides Omega. Through a competitive contract solicitation, NAVAIR awarded both Omega and CASS Professional Services Corporation with an indefinite-delivery indefinite-quantity contract with a 5-year base period and an additional 5-year option.[2] According to NAVAIR officials who administer the contracts, the two contractors will compete at the task order level and NAVAIR will issue orders based on the offer that provides the best value. These officials stated that this competition will serve as a mechanism to help minimize costs. For the first time, the contractors will have aircraft that will be outfitted with a boom, which would allow the contractors to provide aerial refueling service to the Air Force, as well as the limited amount of DON assets, such as F-16s, P-8s, and E-6s with boom refueling requirements. According to Omega and DON, Omega has procured two KDC-10 aircraft with booms that are expected to begin conducting boom refueling with the Navy in January 2022. Meanwhile, according to NAVAIR officials, CASS Professional Services Corporation will have four KC-135s with multi-point refueling system pods, a centerline boom, and a boom to drogue adapter available to support the DON—three of these KC-135s are already in service. NAVAIR officials who administer the contracts also said that the contracts have the flexibility to support the Air Force, and that additional refueling hours contracted by the Air Force could reduce the overall aerial refueling costs.

Lack of Directly Comparable Data Limits Ability to Compare Contracted to Government Aerial Refueling Costs

The lack of comparable cost data makes it difficult to measure the cost of aerial refueling service by a contractor against that which is provided by the government. According to NAVAIR officials, NAVAIR has not conducted a recent comparison of the cost of aerial refueling service provided by contractors with air service provided directly by DOD.[3] Various methods to calculate costs include and exclude different

[2]Indefinite-delivery, indefinite-quantity contracts are awarded to one or more contractors when the exact quantities and timing of products and services are not known at the time of award. FAR 16.504.

[3]In 2003, The Center of Naval Analyses released "Commercial Inflight Refueling" which compared the costs of the U.S. Navy's commercial aerial refueling pilot program with the costs of aerial refueling provided by the Air Force aerial refueling fleet. The study concluded that operating and support costs were lower for the contracted aerial refueling aircraft compared to the Air Force's KC-135, but that the annual cost of service per tanker was higher for the contracted aircraft because of the higher number of flight hours.

components. For example, DON's expenditures for contracted aerial refueling services do not include fuel. From the government's perspective, DOD has established reimbursable rates for the Air Force to lease out its aerial refueling tanker fleet to other entities. This could be used to compare the marginal rate per hour to contracted service, but it excludes costs such as operations personnel, system specific training, and software maintenance. The Air Force's forthcoming study to support its decision of whether or not to develop its own contracted air services program will include a comparative analysis of the costs of providing aerial refueling support by contractors and the government. NAVAIR Contracted Air Services, which is responsible for administering the DON's aerial refueling service contracts, will serve as a subject matter expert resource for the study.

Appendix III: Comments from the Department of Defense

DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

22/12/2021

OFFICE OF THE ASSISTANT SECRETARY

Mr. Jon 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, GAO-22-104530, "KC-46 TANKER: Air Force Needs to Mature Critical Technologies in New Aerial Refueling System Design," dated November 19, 2021 (GAO Code 104530).

The Department appreciates the effort of the GAO and the opportunity to comment on the draft report.

Sincerely,

COSTELLO.DARLENE.J.1043997684 Digitally signed by COSTELLO.DARLENE.J.1043997684 Date: 2021.12.22 14:17:41 -05'00'

Darlene Costello
Acting

Attachment:
As stated

GAO DRAFT REPORT DATED NOVEMBER 19, 2021
GAO-22-104530 (GAO CODE 104530)

"KC-46 TANKER: AIR FORCE NEEDS TO MATURE CRITICAL TECHNOLOGIES IN NEW AERIAL REFUELING SYSTEM DESIGN"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATION

RECOMMENDATION 1: The Secretary of the Air Force should direct KC-46 program officials to complete an independent Technical Readiness Assessment (TRA) of the redesigned Remote Vision System's (RVS) critical technologies prior to closing the preliminary design review or as soon as possible thereafter, to ensure a comprehensive understanding of the maturity of the critical technologies.

DoD RESPONSE: The Department of Defense (DoD) non-concurs with this recommendation. The Memorandum of Agreement signed between the Air Force and Boeing established a non-standard acquisition framework to deliver an improved RVS on an accelerated timeline. To facilitate this acquisition framework and accelerated timeline, a Joint Technical Team comprised of leading experts from both government and industry convened to develop the best practical design. The design was evaluated and vetted to a level of detail that exceeds what would normally exist at a traditional preliminary design review. Based upon the level of effort put into the design at its early stages, it is unlikely that a Technical Readiness Assessment would discover significant risks not already identified and tracked by the program. A TRA would require between six and 12 months to accomplish and would either be too late to affect the design or result in delays to fielding RVS 2.0 if it were made a prerequisite for completing preliminary design review. The Air Force uses a robust Risk, Issue, and Opportunity program coupled with tightly-monitored Technical Performance Measures to provide a comprehensive understanding of the maturity of the critical technologies in the RVS 2.0 design.

RECOMMENDATION 2: The Secretary of the Air Force should direct KC-46 program officials, in coordination with Boeing and prior to closing the preliminary design review or as soon as possible thereafter, to develop Technical Maturation Plans (TMPs) for the Remote Vision System's (RVS) critical technologies.

DoD RESPONSE: DoD non-concurs with this recommendation. The Memorandum of Agreement signed between the USAF and Boeing established a non-standard acquisition framework to deliver an improved RVS on an accelerated timeline. In order to deliver RVS 2.0 at the speed of relevance to the warfighter, a multi-faceted Risk, Issue, and Opportunity process is being used in lieu of a traditional TMP. Each identified risk to technical performance has a comprehensive plan to mature the technology, reduce risk, and reach the required performance objectives. Technical Performance Measures are regularly reviewed to ensure technical performance continues to meet desired targets as the design is matured. At this stage in the

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program, a TMP would consume additional resources, add schedule risk, and duplicate ongoing efforts conducted through other formal critical technology maturation processes.

RECOMMENDATION 3: The Secretary of the Air Force should direct KC-46 program officials to test a full prototype of the Remote Vision System (RVS) on a KC-46 in an operational environment prior to closing the preliminary design review or as soon as possible thereafter.

DoD RESPONSE: DoD non-concurs with this recommendation. Due to the highly-integrated nature of the RVS 2.0 design, which combines upgraded sensors with a new display system, a full prototype prior to preliminary design review closure is not practical. The time required to develop an integrated prototype is similar to the time necessary to get the first developmental test article. Directing a prototype as a prerequisite for preliminary design review closure would result in a program delay of approximately 18 to 24 months and significantly delay fielding the RVS 2.0 system to the warfighter. Prototypes of the cameras have already flown, with further flights scheduled in the third quarter of Fiscal Year 2022 to evaluate the stereoscopic (three-dimensional) performance. Additionally, prototypes of the RVS 2.0 display system have been evaluated in the laboratory and sensitivity analyses confirmed the flight environment will not result in degraded performance. Developmental and operational testing will fully evaluate the RVS 2.0 system in an operationally representative environment prior to any fielding decision.

OVERALL DoD COMMENT: The draft GAO Report intimates that the RVS 2.0 system design is comprehensively deficient, and in so doing, overlooks the fact that the Air Force made extraordinary efforts to ensure the RVS 2.0 design will meet warfighter requirements while accelerating the RVS 2.0 development to meet warfighter operational demands. The KC-46 RVS 2.0 system will provide significantly enhanced capability to the warfighter over the KC-135 and KC-10 aircraft. Altogether, the RVS 2.0 design process has proven to be highly successful and is on track to meet or exceed all but one relevant contract requirement. Boeing and the Air Force are working collaboratively on a corrective action plan to address this requirement. However, this shortfall, which must be addressed, should not overshadow the considerable benefit to the warfighter derived from the KC-46 RVS 2.0 system design and accelerated development and fielding timelines.

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Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

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Staff Acknowledgments

In addition to the contact named above, Justin Jaynes (Assistant Director), Ashley Rawson (Analyst-in-Charge), Matt Shaffer, and Monique Nasrallah were key contributors to this report. Other contributors included Lori Fields, Kurt Gurka, Stephanie Gustafson, and Edward J. SanFilippo.

Related GAO Products

GAO. *KC-46 Tanker Modernization: Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct.* GAO-19-480. Washington, D.C.: June 12, 2019.

GAO. KC-46 *Tanker Modernization: Program Cost is Stable, but Schedule May Be Further Delayed.* GAO-18-353. Washington, D.C.: April 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.: March 24, 2017.

GAO. *KC-46 Tanker Aircraft: Challenging Testing and Delivery Schedules Lie Ahead.* GAO-16-346. Washington, D.C.: April 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.: April 9, 2015.

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GAO. *KC-46 Tanker Aircraft: Program Generally Stable but Improvements in Managing Schedule Are Needed.* GAO-13-258. Washington, D.C.: February 27, 2013.

GAO. *KC-46 Tanker Aircraft: Acquisition Plans Have Good Features but Contain Schedule Risk.* GAO-12-366. Washington, D.C.: March 26, 2012.