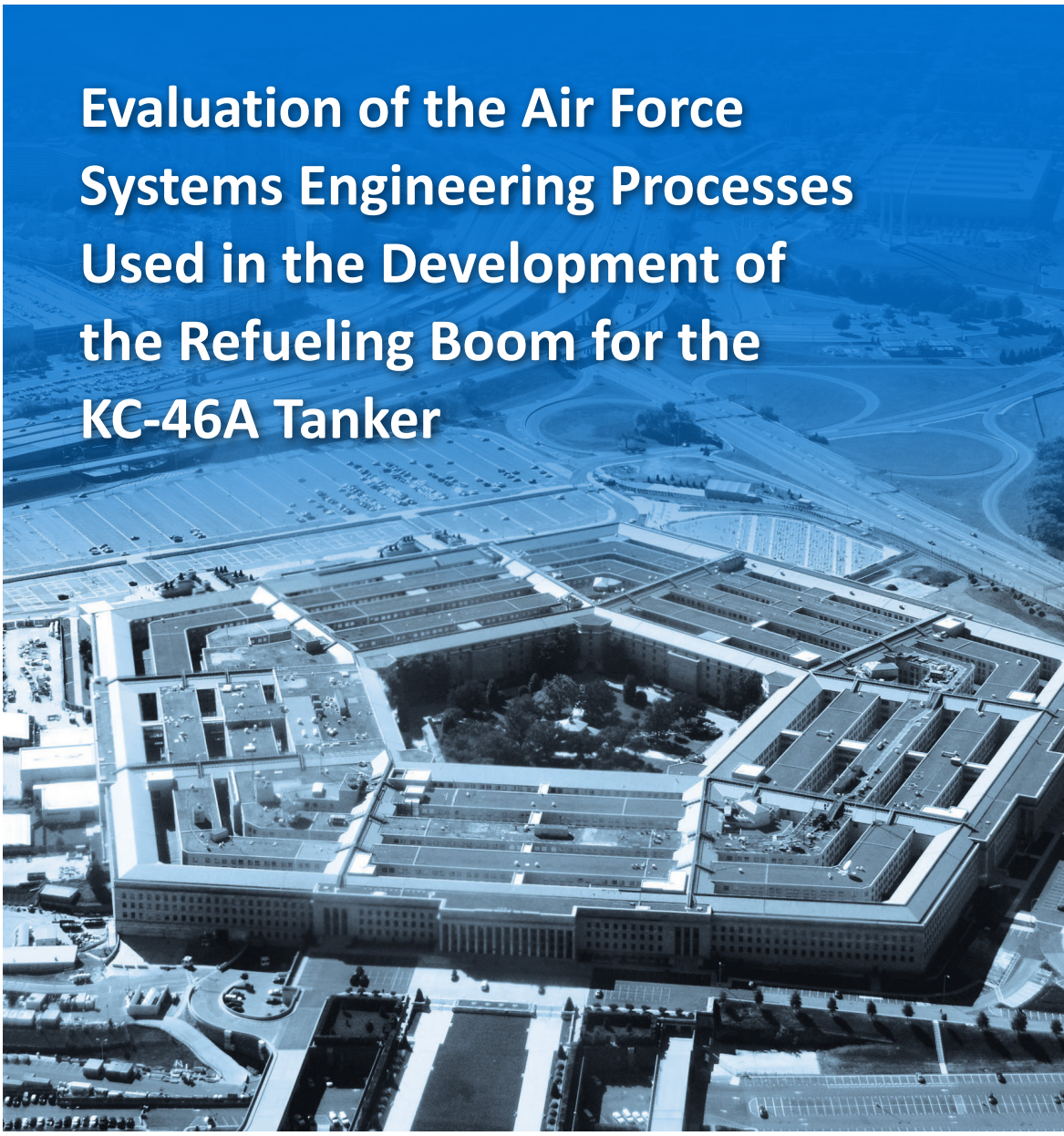
Report No. DODIG-2021-088

INSPECTOR GENERAL

U.S. Department of Defense

MAY 21, 2021

Evaluation of the Air Force Systems Engineering Processes Used in the Development of the Refueling Boom for the KC-46A Tanker



INTEGRITY ★ INDEPENDENCE ★ EXCELLENCE


INSPECTOR GENERAL
INTEGRITY
EFFICIENCY
DEPARTMENT OF DEFENSE

Results in Brief

Evaluation of the Air Force Systems Engineering Processes Used in the Development of the Refueling Boom for the KC-46A Tanker

May 21, 2021

Objective

The objective of this evaluation was to determine whether the Air Force adhered to DoD and Air Force systems engineering processes during the design and development of the KC-46A aerial refueling boom.

Background

The KC-46A Pegasus tanker is an aircraft whose mission is aerial refueling of DoD and Allied aircraft. The refueling boom is the component of the aerial refueling system that transfers fuel from the tanker to the receiver aircraft.

In February 2011, the Air Force awarded a fixed-price-incentive contract for the KC-46A tanker to Boeing. Under this contract, Boeing is responsible for designing, developing, testing, and manufacturing 179 KC-46A tankers for delivery to the Air Force. The Air Force contracted with Boeing to deliver the KC-46A tankers in August 2017; however, deliveries did not begin until January 2019. As of October 2020, Boeing delivered 38 of the required 179 KC-46A tankers to the Air Force.

Finding

KC-46 Program Office officials did not effectively manage the development of the refueling boom for the KC-46A tanker. Specifically, KC-46 Program Office officials:

- did not ensure that critical technologies for the refueling boom were demonstrated in a relevant testing environment after Boeing officials presented a system design at the preliminary design review in 2012 that differed significantly from the initially proposed design; and
- did not verify full functionality of the KC-46A tanker refueling boom in accordance with the program's Test and Evaluation Master Plan when they performed flight testing of the KC-46A tanker refueling boom with Air Force receiver aircraft.

Finding (cont'd)

These shortfalls with the KC-46A refueling boom occurred because:

- officials from the KC-46 Program Office did not revalidate changes to critical technologies or technology maturity at any point during the engineering and manufacturing development phase, since revalidations were not required by DoD policy; and
- officials from the KC-46 Program Office decided, and officials from the Office of the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation accepted, in 2014 that reduced flight testing was sufficient to evaluate the performance of the KC-46A tanker in support of the Milestone C decision in 2016. Despite encountering flight test failures in January 2016 that required Boeing engineers to redesign the refueling boom, the KC-46 Program Office officials did not change their decision to perform reduced flight testing prior to the Milestone C decision. This reduced flight testing did not include the stressing conditions under which the refueling boom problem could potentially occur.

As a result, in 2018, when Boeing attempted to test full functionality of the KC-46A tanker refueling boom after Milestone C, flight test reports documented that refueling boom performance remained a problem during in-flight refueling of the A-10, C-17, and F-16 receiver aircraft. Specifically, the 38 KC-46A tankers that Boeing delivered could not refuel the A-10 or several variants of the

Results in Brief

Evaluation of the Air Force Systems Engineering Processes Used in the Development of the Refueling Boom for the KC-46A Tanker

Finding (cont'd)

C-130 receiver aircraft, and Air Force officials imposed operational limitations allowing the B-52, C-17, F-15, F-16, F-35A, HC/MC-130J, KC-10, KC-46A, and KC-135 receiver aircraft to aerially refuel only under limited flight conditions.

In August 2019 and March 2020, the Air Force issued contract modifications, valued at $100 million, for the redesign of the KC-46A tanker refueling boom. Had KC-46 Program Office officials effectively managed the development and testing of the refueling boom for the KC-46A tanker, the Air Force would not have had to spend an additional $100 million for the redesign of the refueling boom to achieve its required performance. Furthermore, retrofit of the refueling boom for the delivered KC-46A tankers is not estimated to begin until January 2024, and will result in additional undetermined costs, as well as approximately a 5-year delayed delivery of the first KC-46A tankers with fully mission-capable refueling booms. This delay limits the DoD's use of the KC-46A tanker for its intended refueling missions.

Recommendations

We recommend that the Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment revise DoD acquisition policy to require program managers of major defense acquisition programs to:

- Conduct knowledge-building technology readiness assessments throughout the acquisition life cycle, including at preliminary design review, critical design review, and Milestone C, at a minimum.
- Develop and execute technology maturation plans for critical technologies that have not been demonstrated in a relevant testing environment, as determined by a knowledge-building or statutory technology readiness assessment.

Additionally, we revised the following two recommendations:

- Use scientific test and analysis techniques to the maximum extent possible to develop the Test and Evaluation Master Plan.
- Use scientific test and analysis techniques to the maximum extent possible to justify the elimination, deferral, or modification of planned tests that were originally documented in the Test and Evaluation Master Plan.

Finally, we added two recommendations:

- Include the most critical or stressing test conditions in the Test and Evaluation Master Plan for any tests where the use of scientific test and analysis techniques is impractical or not applicable when developing the Test and Evaluation Master Plan.
- Include the most critical or stressing test conditions in revised test plans when proposing elimination, deferral, or modification of planned tests that were originally documented in the Test and Evaluation Master Plan.

Management Comments and Our Response

The Director of Developmental Test, Evaluation, and Assessments, responding for the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment, agreed with two recommendations related to the use of knowledge-building technology readiness assessments and technology maturation plans. Additionally, the Director partially agreed with the two recommendations related to the use of scientific test and analysis techniques to develop the Test

Comments (cont'd)

and Evaluation Master Plan and for proposing the elimination, modification, or deferral of planned tests documented in the Test and Evaluation Master Plan.

Although the Director agreed, his comments only partially addressed our recommendations. Therefore, the recommendations are unresolved.

We request that the Director provide additional comments on the final report to describe the specific actions that the USD(R&E), in coordination with the USD(A&S), will take to address the recommendations. Management comments and our response are discussed in detail in the Recommendations, Management Comments, and Our Response section of this report.

Please see the Recommendations Table on the next page for the status of recommendations.

Recommendations Table

Management	Recommendations Unresolved	Recommendations Resolved	Recommendations Closed
Under Secretary of Defense for Research and Engineering	1.a, 1.b, 1.c, 1.d, 1.e, 1.f	None	None
Under Secretary of Defense for Acquisition and Sustainment	1.a, 1.b, 1.c, 1.d, 1.e, 1.f	None	None

Please provide Management Comments by June 21, 2021.

Note: The following categories are used to describe agency management's comments to individual recommendations.

- **Unresolved** – Management has not agreed to implement the recommendation or has not proposed actions that will address the recommendation.
- **Resolved** – Management agreed to implement the recommendation or has proposed actions that will address the underlying finding that generated the recommendation.
- **Closed** – OIG verified that the agreed upon corrective actions were implemented.

INSPECTOR GENERAL
DEPARTMENT OF DEFENSE
4800 MARK CENTER DRIVE
ALEXANDRIA, VIRGINIA 22350-1500

May 21, 2021

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING
UNDER SECRETARY OF DEFENSE FOR ACQUISITION AND SUSTAINMENT
AUDITOR GENERAL, DEPARTMENT OF THE AIR FORCE

SUBJECT: Evaluation of the Air Force Systems Engineering Processes Used in the Development of the Refueling Boom for the KC-46A Tanker (Report No. DODIG-2021-088)

This final report provides the results of the DoD Office of Inspector General's evaluation. We previously provided copies of the draft report and requested written comments on the recommendations. We considered management's comments on the draft report when preparing the final report. These comments are included in the report.

This report contains recommendations that are unresolved. Comments from the Director of Developmental Test, Evaluation, and Assessments, responding for the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment, partially addressed the recommendations. Additionally, we made two new recommendations that require comment from the Director.

Therefore, as discussed in the Recommendations, Management Comments, and Our Response section of this report, the recommendations remain open. We will track these recommendations until an agreement is reached on the actions that you will take to address the recommendations, and you have submitted adequate documentation showing that all agreed-upon actions are completed.

DoD Instruction 7650.03 requires that recommendations be resolved promptly. Therefore, please provide us within 30 days your response concerning specific actions in process or alternative corrective actions proposed on the recommendations. [redacted]

[redacted]

Randolph R. Stone
Assistant Inspector General for Evaluations
Space, Intelligence, Engineering, and Oversight

Contents

Introduction

Objective

The objective of this evaluation was to determine whether the Air Force adhered to DoD and Air Force systems engineering processes during the design and development of the KC-46A tanker refueling boom.[1] Specifically, we determined whether the systems engineering processes for the KC-46A Tanker Modernization program led to a critical deficiency with the KC-46A tanker aerial refueling capability that the Air Force encountered during post-Milestone C flight testing.

Background

Defense Acquisition System Milestones

DoD Directive 5000.01 establishes the policies and principles that govern the defense acquisition system, and forms the management foundation for all DoD acquisition programs.[2] The defense acquisition system's primary objective is to acquire quality products and satisfy user needs with measurable improvement in mission. The defense acquisition system's major capability acquisition process includes three DoD program decision points to assess a program's readiness to proceed to the next acquisition phase—Milestone A, Milestone B, and Milestone C. The milestone decision authority decides whether the program is ready to transition to the next acquisition phase and is the sole and final decision authority.[3]

At the Milestone A decision, the milestone decision authority decides whether an acquisition program can enter the technology maturation and risk reduction phase, where program officials reduce the weapon systems risks, develop capability requirements, and finalize affordability caps. At the Milestone A review, program officials present program documentation, such as their acquisition strategy, program risk assessment, and affordability analysis, to the milestone decision authority.

At the Milestone B decision, the milestone decision authority decides whether an acquisition program can enter the engineering and manufacturing development phase where program officials develop, build, and test that the weapon system

[1] Air Force Instruction 63-1201, "Life Cycle Systems Engineering," defines systems engineering as an interdisciplinary approach encompassing the entire set of scientific, technical, and managerial efforts needed to evolve, verify, deploy, and support an integrated and life-cycle-balanced set of system solutions that satisfy customer needs. The refueling boom is the component of the aerial refueling system that transfers fuel from the KC-46A tanker to the receiver aircraft.

[2] DoD Directive 5000.01, "The Defense Acquisition System," September 9, 2020.

[3] The milestone decision authority for the KC-46A tanker program was the Under Secretary of Defense for Acquisition, Testing and Logistics until November 2017, when the Under Secretary of Defense for Acquisition and Sustainment delegated the milestone decision authority to the Secretary of the Air Force.

meets all requirements to support production or deployment decisions. At the Milestone B review, program officials present program documentation to the milestone decision authority, such as their desired capability requirements, an independent cost estimate, and the acquisition program baseline.

At the Milestone C decision, the milestone decision authority decides whether an acquisition program can enter the production and deployment phase where program officials produce and deliver requirements-compliant products to receiving military organizations. At the Milestone C review, program officials present program documentation to the milestone decision authority to demonstrate that the weapon system is stable, within the approved affordability caps, and will meet requirements.

Developmental Test and Evaluation

Developmental test and evaluation is conducted throughout the acquisition process to assist in engineering design and development and to verify that technical performance specifications have been met. The Test and Evaluation Master Plan (TEMP) serves as the primary document for managing a test and evaluation program. The TEMP contains an integrated test program summary and master schedule of all major test events or test phases. Program officials update the TEMP as needed to support acquisition milestones and decision points. The program manager uses the TEMP as the planning and management tool for all program test activities.

KC-46A Tanker Modernization Program

The KC-46A Tanker Modernization program is a major defense acquisition program.[4] In February 2011, the Air Force awarded a contract to The Boeing Company (Boeing) to develop an aerial refueling tanker by modifying a commercial 767 passenger aircraft and designated this modified aircraft the KC-46A Pegasus tanker, shown in Figure 1. The KC-46A Pegasus tanker is an aircraft whose mission is aerial refueling of DoD and allied aircraft. Boeing is currently producing the KC-46A tanker for the Air Force to replace its aging fleet of KC-135 tanker aircraft that have been a significant component of the DoD's refueling aircraft fleet since approximately 1956.

An integral part of the KC-46A modernization program is the refueling boom. Figure 1 illustrates the location of the refueling boom at the rear of the KC-46A tanker. Figure 2 illustrates the components that make up the refueling

[4] Section 2430, title 10, United States Code, 2012, defines a major defense acquisition program as a DoD acquisition program that is either designated by the Secretary of Defense as a major defense acquisition program or that is estimated for all increments of the program to require an eventual total expenditure for research, development, and test and evaluation of more than $525 million in fiscal year 2020 constant dollars or, for procurement, of more than $3.065 billion in fiscal year 2020 constant dollars.

boom, including the pivot point where the boom mounts to the KC-46A tanker, the telescoping section that moves in and out to accommodate movement of receiver aircraft during refueling operations, and the nozzle that transfers fuel to receiver aircraft. In addition to the refueling boom, the KC-46A tanker is equipped with a centerline drogue refueling system and wing aerial refueling pods which provide expanded aerial refueling capabilities.[5]

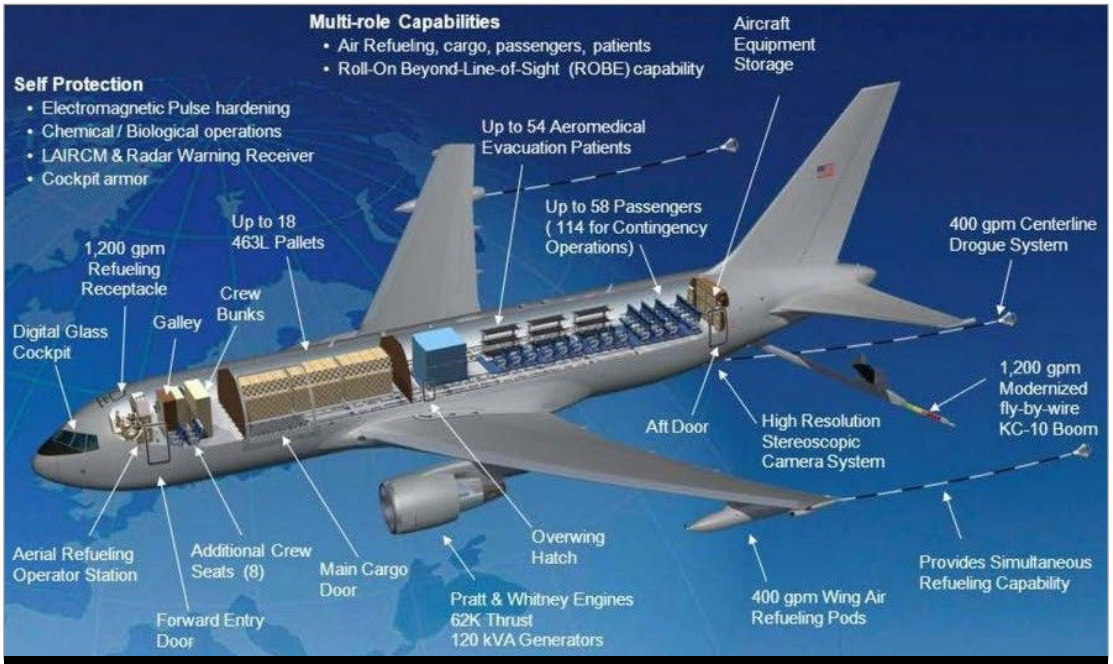


Figure 1. KC-46A Tanker Key Features
Source: The Air Force.

[5] A drogue refueling system consists of a funnel-shaped device that is attached to the end of a long flexible hose suspended from a tanker aircraft in flight and into which the probe of a receiver aircraft connects to receive fuel from the tanker.

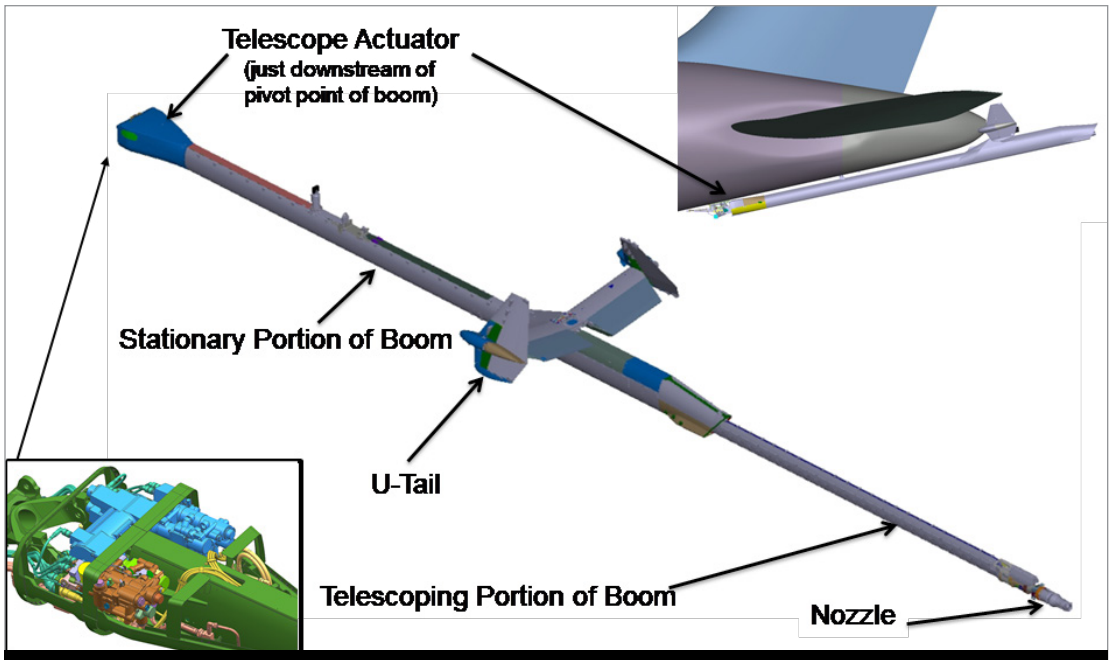


Figure 2. KC-46A Tanker Refueling Boom
Source: The Air Force.

The refueling boom is the component of the aerial refueling system that transfers fuel from the KC-46A tanker to the receiver aircraft. A receiver aircraft is any DoD or allied aircraft capable of being aerially refueled. During aerial refueling, an operator on the KC-46A tanker extends the refueling boom into a receptacle on the receiving aircraft to transfer fuel. The goal of aerial refueling is to extend the range or time a receiver aircraft can remain in the air.

The Air Force Initiated the KC-46A Tanker Modernization Program in 2011

In February 2011, KC-46 Program Office officials initiated the KC-46A Tanker Modernization program at Milestone B and entered the engineering and manufacturing development phase of the DoD acquisition process. Shortly after program initiation in 2011, Air Force officials awarded Boeing a fixed-price-incentive contract for the acquisition of 4 KC-46A tankers. Including options to procure up to an additional 175 KC-46A tankers, for a total of 179 aircraft, this contract was valued at $41.5 billion. The engineering and manufacturing development phase of the KC-46A Tanker Modernization program ended in August 2016, upon Milestone C approval. The Air Force contract required Boeing to deliver the KC-46A tankers in August 2017; however, deliveries did not begin until January 2019. As of October 2020, Boeing had delivered 38 of the 179 KC-46A tankers to the Air Force.

KC-46A Tanker Refueling Boom Performance

During developmental testing prior to Milestone C in early 2016, Air Force pilots reported performance problems to KC-46 Program Office officials regarding the operation of the KC-46A tanker refueling boom with C-17 receiver aircraft.[6] Specifically, the boom axial loads were too high during testing, meaning that the boom was too stiff and would not extend or retract during flight testing unless subjected to more force than the system performance specification required.[7] Initially, Boeing engineers implemented software updates to the refueling boom control system in an attempt to optimize the performance of the refueling boom, and then decided to pursue a software and hardware solution to reduce refueling boom axial forces. However, after Boeing engineers made software and hardware updates, additional flight tests in 2018 demonstrated that refueling boom performance remained a problem due to high axial loads during in-flight refueling of the A-10, C-17, and F-16 receiver aircraft.

The refueling boom performance problems caused Air Force Materiel Command flight test officials to issue a Category I performance deficiency in September 2018, identifying the boom as being too stiff while in contact with the receiver aircraft.[8] The performance deficiency report stated that excessive receiver aircraft engine thrust was necessary to compress the boom under certain aerial refueling conditions. Additionally, the deficiency report documented that receiver aircraft needed to make large engine power corrections when attempting to make a forward or backward position adjustment to maintain contact with the refueling boom. The large engine power corrections could result in potentially unsafe flight operations during the process of disconnecting the receiver aircraft from the refueling boom. Because the refueling boom was too stiff, it caused pilots of receiver aircraft to inadvertently use excess engine power or not use enough engine power, which, upon disconnecting from the refueling boom, could cause the receiver aircraft to rapidly accelerate toward or away from the tanker. The rapid aircraft acceleration could cause the receiver aircraft to lunge into the refueling boom, potentially causing damage to the receiver aircraft, the refueling boom, or both.

[6] Developmental test and evaluation is conducted throughout the acquisition process to assist in engineering design and development and to verify that technical performance specifications have been met.

[7] Axial load is the force applied on a structure directly along an axis.

[8] According to Air Force Instruction 99-103, "Capabilities-Based Test and Evaluation," Category I deficiencies are those that may cause death, severe injury, or severe occupational illness; may cause loss or major damage to a weapon system; critically restrict the combat readiness capabilities of the using organization; or result in a production line stoppage. Boeing engineers designed the KC-46A tanker refueling boom to extend and retract, adjusting the length of the boom so that contact with the receiver aircraft can be maintained for aerial refueling operations.

Subsequently, in December 2018, KC-46 Program Office officials established new technical requirements for the redesign of the KC-46A tanker refueling boom and issued associated contract modifications in 2019 and 2020. As of October 2020, Boeing had delivered 38 of the 179 KC-46A tankers to the Air Force. However, the 38 KC-46A tankers that were delivered did not have the redesigned refueling boom and, as a result, none of the delivered tankers could refuel the A-10 or several variants of the C-130 receiver aircraft.[9] To address the refueling boom deficiencies, the Air Force imposed operational limitations on these 38 tankers allowing the B-52, C-17, F-15, F-16, F-35A, HC/MC-130J, KC-10, KC-46A, and KC-135 receiver aircraft to be aerially refueled only under limited flight conditions. Examples of limited flight conditions included reduced tanker refueling boom range of motion and no refueling in a covert or lights-out scenario.

KC-46A Tanker Modernization Program Stakeholders

There are several DoD and Air Force organizations that have roles and responsibilities for the KC-46A program.

Air Force Life Cycle Management Center

The Air Force Life Cycle Management Center (AFLCMC) is located at Wright-Patterson Air Force Base in Dayton, Ohio. The AFLCMC is responsible for life cycle management of Air Force weapon systems from inception to retirement. Ten Program Executive Officers within AFLCMC, including the Program Executive Officer for the Mobility and Training Aircraft Directorate, are responsible for the activities within their respective portfolio and report to the Assistant Secretary of the Air Force for Acquisition.[10]

KC-46 Program Office

The KC-46 Division of the AFLCMC Mobility and Training Aircraft Directorate (KC-46 Program Office) is responsible for the planning and execution of all life-cycle activities for the Air Force's KC-46A tanker fleet. The KC-46 Program Office is located at Wright-Patterson Air Force Base, Ohio. The life-cycle activities that the KC-46 Program Office is responsible for include the development, test, production, fielding, and support of the KC-46A tanker.

[9] The variants of the C-130 aircraft that the KC-46A tanker could not refuel included the AC-130J, AC-130W, EC-130J, MC-130H, and MC-130J.

[10] In May 2020, the Air Force reorganized the AFLCMC, realigning three tanker program offices from the Tanker Directorate to the Mobility and Training Aircraft Directorate.

Deputy Assistant Secretary of Defense for Developmental Test and Evaluation

Prior to June 2018, the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation (DASD[DT&E]) was the principal advisor to the then-Secretary of Defense and the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD[AT&L]).[11] The DASD(DT&E)'s primary responsibilities included establishing policy and guidance for the conduct of developmental test and evaluation in the DoD and assessing the developmental test and evaluation activities of each major defense acquisition program.

DoD Revised Acquisition Policy During the KC-46A Tanker Modernization Program

During the engineering and manufacturing development phase of the KC-46A Tanker Modernization program, the DoD revised DoD Instruction (DoDI) 5000.02 twice—once in November 2013 and again in January 2015.[12] The version of DoDI 5000.02 issued in December 2008, in effect at Milestone B of the KC-46A Tanker Modernization program, required Acquisition Category ID programs—such as the KC-46A Tanker Modernization program—to conduct a technology readiness assessment (TRA) at both Milestone B and Milestone C.[13] A TRA is a formal metrics-based process and accompanying report that assesses the maturity of critical hardware and software technologies called critical technology elements. In November 2013, DoDI 5000.02 was revised to require all major defense acquisition programs to conduct a TRA before release of development contract requests for proposal, with updates to the TRA before Milestone B if changes had occurred, and a TRA at Milestone C only if the program was initiated at Milestone C. DoDI 5000.02 was revised again in January 2015; however, the requirements related to TRAs remained the same as in the version of DoDI 5000.02 issued in 2013.

---

[11] As of June 25, 2018, in accordance with Public Law 114-328, the "National Defense Authorization Act for Fiscal Year 2017," Section 901, "Organization of the Office of the Secretary of Defense," the DoD reorganized the Office of the USD(AT&L) to establish the Office of the Under Secretary of Defense for Research and Engineering and the Office of the Under Secretary of Defense for Acquisition and Sustainment. Additionally, the DoD reorganized the Office of the DASD(DT&E) to establish the Office of the Deputy Director for Developmental Test, Evaluation, and Prototyping within the Office of the Under Secretary of Defense for Research and Engineering.

[12] DoDI 5000.02, "Operation of the Defense Acquisition System," December 8, 2008. DoDI 5000.02, "Operation of the Defense Acquisition System," November 26, 2013. DoDI 5000.02, "Operation of the Defense Acquisition System," January 7, 2015.

[13] An Acquisition Category ID program is a major defense acquisition program, as defined in Section 2430, title 10, United States Code, for which the Under Secretary of Defense for Acquisition and Sustainment makes a decision to become the milestone decision authority or designate another Office of the Secretary of Defense official as the milestone decision authority. The milestone decision authority is the designated individual with overall responsibility for a program and with the authority to approve entry of an acquisition program into the next phase of the acquisition process.

In January 2020, the DoD further restructured the acquisition process, referred to as the Adaptive Acquisition Framework, which established six acquisition "pathways," including the major capability acquisition pathway.[14] Accordingly, in August 2020, the DoD issued DoDI 5000.85 to establish policy and prescribe procedures that guide the acquisition of major capability acquisition programs, including major defense acquisition programs.[15] Additionally, in November 2020, the DoD issued DoDI 5000.88 to establish policy, assign responsibilities, and provide procedures for the engineering management activities necessary to guide the development of defense systems.[16]

[14] DoDI 5000.02, "Operation of the Adaptive Acquisition Framework," January 23, 2020.

[15] DoDI 5000.85, "Major Capability Acquisition," August 6, 2020.

[16] DoDI 5000.88, "Engineering of Defense Systems," November 18, 2020.

Finding

The KC-46 Program Office Did Not Effectively Manage the Development of the KC-46A Tanker Refueling Boom

KC-46 Program Office officials did not effectively manage the development of the refueling boom for the KC-46A tanker. Specifically, KC-46 Program Office officials:

- did not ensure that critical technologies for the refueling boom were demonstrated in a relevant testing environment after Boeing officials presented a system design at the preliminary design review in 2012 that differed significantly from the initially proposed design; and
- did not verify full functionality of the KC-46A tanker refueling boom in accordance with the program's TEMP when the Air Force performed flight testing of the KC-46A tanker refueling boom with Air Force receiver aircraft, including the A-10, C-17, and F-16, in 2016.

These shortfalls with the KC-46A refueling boom occurred because:

- officials from the KC-46 Program Office did not revalidate changes to critical technologies or technology maturity during the engineering and manufacturing development phase since revalidations were not required by any version of DoDI 5000.02; and
- officials from the KC-46 Program Office decided, and officials from the Office of the DASD(DT&E) accepted, in 2014 that reduced flight testing was sufficient to evaluate the performance of the KC-46A tanker in support of the Milestone C decision in 2016. Despite encountering KC-46A flight test failures in January 2016 that required Boeing engineers to redesign the refueling boom, the KC-46 Program Office officials did not change their decision to perform reduced flight testing prior to the Milestone C decision. This reduced flight testing did not include the stressing conditions under which the refueling boom problem could potentially occur.

As a result, despite actions by Boeing to correct the refueling boom performance problems, when Boeing attempted to test full functionality of the KC-46A tanker refueling boom after Milestone C in 2018, flight test reports documented that refueling boom performance remained a problem during in-flight refueling of the A-10, C-17, and F-16 receiver aircraft. As of October 2020, Boeing had delivered 38 of 179 total KC-46A tankers to the Air Force, however, the 38 KC-46A tankers that Boeing delivered could not refuel the A-10 or several variants of the C-130 receiver aircraft. In addition, the DoD continued to experience problems when refueling the B-52, C-17, F-15, F-16, F-35A, HC/MC-130J, KC-10, KC-46A, and KC-135 receiver aircraft, which the Air Force addressed by limiting the flight conditions for aerial refueling operations with these receiver aircraft.

The Air Force issued contract modifications in August 2019 and March 2020, valued at $100 million, for the redesign of the KC-46A tanker refueling boom. These modifications did not include the acquisition of the redesigned refueling booms and their installation on the KC-46A aircraft already delivered. The associated contract modifications will be negotiated at a later time. According to the KC-46A program officials, the Air Force plans to start the installation of the redesigned refueling booms on the delivered KC-46A aircraft in January 2024. Had KC-46 Program Office officials effectively managed the development and testing of the refueling boom for the KC-46A tanker, the Air Force would not have had to spend an additional $100 million for the redesign of the refueling boom to achieve its required performance. Furthermore, retrofit of the refueling boom for the delivered KC-46A tankers is not estimated to begin until January 2024, and will result in a delay of approximately 5 years for the delivery of the first KC-46A tankers with full mission-capable refueling booms. This delay limits the DoD's use of the KC-46A tanker for its intended refueling missions. Additionally, the Commander of United States Transportation Command identified the aerial refueling fleet as the most stressed of the air mobility forces, and stated that any delay of the KC-46 production puts the Joint Force's ability to effectively execute war plans at risk. Finally, Congress included minimum inventory requirements and prohibitions on the retirement of legacy KC-10 and KC-135 refueling tankers in the FY 2021 National Defense Authorization Act.

The KC-46 Program Office Did Not Ensure Critical Technologies for the Refueling Boom Were Demonstrated in a Relevant Testing Environment

The KC-46 Program Office did not ensure that critical technologies for the KC-46A tanker refueling boom were demonstrated in a relevant testing environment after Boeing officials presented a system design at the preliminary design review in 2012 that differed significantly from the proposed design at the time of the TRA for the Milestone B decision in 2011.[17] Section 2366b, title 10, United States Code, 2010, requires the milestone decision authority to certify, based on an independent review, that technology in a major defense acquisition program has been "demonstrated in a relevant environment" prior to Milestone B approval. The DoD defines a relevant environment as "a testing environment that simulates both the most important and most stressing aspects of the operational environment."[18]

[17] Preliminary design review is a technical assessment to ensure the preliminary design and basic system architecture are complete, that there is technical confidence the capability need can be satisfied within cost and schedule goals, and that risks have been identified and mitigation plans established.

[18] The DoD Technology Readiness Assessment (TRA) Deskbook, published in 2009, provides definitions of terms associated with technology maturity, including "relevant environment" and "critical technology element."

In accordance with the DoDI 5000.02 that was in effect during the KC-46A Tanker Modernization program Milestone B decision in 2011, technology procured from industry "shall have been demonstrated in a relevant environment or, preferably, in an operational environment to be considered mature enough to use for product development." The DoDI 5000.02 in effect at Milestone B required a program office to conduct a TRA for major defense acquisition programs and provide the results to the milestone decision authority at both Milestone B and Milestone C. However, prior to the KC-46A Tanker Modernization program Milestone C decision in August 2016, DoDI 5000.02 was revised to require major defense acquisition programs to conduct a TRA only at the milestone of program initiation in the DoD acquisition life cycle. This policy change eliminated the requirement to conduct a TRA for the KC-46A Tanker Modernization program at Milestone C.

According to DoD TRA guidance, a program office will establish an independent review team of subject matter experts to conduct a TRA. A TRA is a formal metrics-based process and accompanying report that assesses the maturity of critical hardware and software technologies called critical technology elements. A TRA independent review team examines program concepts, technology requirements, and demonstrated capabilities. For the purposes of a TRA, a technology element is critical if "the system being acquired depends on this technology element to meet operational requirements (within acceptable cost and schedule limits) and if the technology element or its application is either new or novel or in an area that poses major technological risk during detailed design or demonstration."[19]

The KC-46 Program Office Conducted a Technology Readiness Assessment and Found the Refueling Boom Was Not a Critical Technology in 2011

In support of the Milestone B decision, the KC-46 Program Office formed an independent review team to conduct a TRA focused on technology readiness of the KC-46A Tanker Modernization Program, which determined that the KC-46A tanker refueling boom was not a critical technology element. The Assistant Secretary of Defense for Research and Engineering approved the TRA report in February 2011. The TRA report stated that the independent review team determined that Boeing engineers used no new or novel technology in the design of the KC-46A tanker refueling boom because the design was "based on that of the well-proven KC-10 [refueling boom] and the control laws [were] based on the Italian KC-767A and Japanese KC-767J control laws."[20] As a result, the independent review team completed no further assessment to ensure that the refueling boom technologies had been demonstrated in a relevant testing environment.

[19] The DoD Technology Readiness Assessment Deskbook, 2009.

[20] Refueling boom control laws are the mathematical rules that control the refueling boom's flight control surfaces and extension of the boom based on the aerial refueling operator's control inputs, so that the boom can be maneuvered throughout its operational envelope (its range of allowable positions and orientations).

According to the TRA report, the independent review team identified the critical technology elements used in the KC-46A tanker based on the results of Boeing's assessment of the technology maturity and information in Boeing's proposal, including:

- mission capability and non-mandatory technical requirements,
- design approach description,
- system development and management plan, and
- contract work breakdown structure.

The TRA report states that when Boeing's proposal lacked enough information to determine whether a technology should be identified as a critical technology element, the independent review team requested additional information from Boeing, and in some cases, the information from Boeing was supplemented with outside research (including technical reports, technical papers, and interviews with subject matter experts).

However, the KC-46 Program Office was unable to provide any documentation that supported the independent review team's determination that the KC-46A tanker refueling boom was not a critical technology element. Therefore, we were unable to independently verify the TRA review team's determination that the KC-46A tanker refueling boom should not have been identified as a critical technology element.

Boeing Officials Presented a Refueling Boom Design to the Air Force in February 2012 that Differed Significantly from the Design in the Technology Readiness Assessment Report in 2011

After the Air Force completed the TRA in 2011, Boeing officials presented refueling boom design details to the Air Force during the preliminary design review in February 2012. We reviewed the preliminary design review documentation and found that it showed a refueling boom design that differed significantly from the proposed design that the independent review team documented in the TRA report.

Based on our analysis of the preliminary design review documentation, we found that the KC-46A tanker refueling boom included a computer control system that was an integral part of its function. In contrast, the mature technology of the KC-10 refueling boom—which the KC-46A tanker refueling boom was proposed to be based upon—did not include a computer control system.

According to Air Force aerial refueling engineers, the KC-10 refueling boom was a hydromechanically controlled system. The KC-10 refueling boom design did not include the measurement of boom axial loads and use of a computer system to actively control refueling boom axial loads. However, the KC-46A refueling boom used sensors and a computer to measure refueling boom axial loads and to process the measurements to actively control movement of the refueling boom. Based on this information, we concluded that the KC-46A refueling boom included new or novel technology and, therefore, should have been identified as a critical technology element.[21] Therefore, KC-46 Program Office officials should have ensured that the refueling boom was demonstrated in a relevant testing environment before proceeding beyond Milestone B.

KC-46 Program Office Officials Did Not Revalidate the TRA When Presented with Information Showing KC-46A Tanker Refueling Boom Technologies Were New or Novel

We found that the KC-46 Program Office did not revalidate the technology readiness assessment of the KC-46A tanker refueling boom after being presented with new technical information during the preliminary design review. Air Force aerial refueling engineers for the KC-46A tanker stated that their first indication the KC-46A tanker refueling boom technology was not based on the KC-10 refueling boom design was during the Milestone C decision in 2016. However, e-mail correspondence between AFLCMC aerial refueling engineers and KC-46 Program Office officials in 2013—before the Milestone C decision in 2016—showed that Air Force aerial refueling engineers were aware that the KC-46A tanker refueling boom relied on a computer control system to function.

AFLCMC aerial refueling engineers and KC-46 Program Office officials told us in 2020 that they would have assessed the KC-46A tanker refueling boom technology to be new or novel if they had known the operation of the refueling boom was computer controlled and not hydromechanically controlled, as in the KC-10.

[21] According to the DoD Technology Readiness Assessment Deskbook, 2009, a critical technology element is a technology element that (1) the system being acquired depends on to meet operational requirements and (2) is either new or novel in application or in an area that poses major technological risk during detailed design or demonstration.

DoD Policy Does Not Require Acquisition Programs to Revalidate Technology Readiness During the Engineering and Manufacturing Development Phase

KC-46 Program Office officials did not revalidate changes to critical technologies or technology maturity during the engineering and manufacturing development phase because revalidations were not, and still are not, required by any version of DoDI 5000.02.[22]

Knowledge-Building Technology Readiness Assessments Are Necessary Throughout System Development

Performing continuous knowledge-building TRAs throughout development could benefit acquisition programs by mitigating the cost and schedule overruns these programs have experienced due to lack of technology maturity.[23] The Government Accountability Office (GAO) best practices recommend reviewing technology maturity as needed throughout the product development life cycle. Additionally, GAO best practices state that TRAs are important inputs into systems engineering events, such as a project's preliminary design review and critical design review, and can expose knowledge gaps.

However, the DoD does not require acquisition programs to conduct a TRA once programs have proceeded beyond Milestone B, unless Milestone C is the point of initiation of the program. If DoD acquisition policy required major defense acquisition programs to revalidate critical technologies and technology maturity throughout the engineering and manufacturing development phase, then KC-46 Program Office officials may have identified the KC-46A tanker refueling boom as a critical technology that needed to be further matured before the program entered production.

According to the GAO's TRA guide, "the expert community has recognized that more frequent, regular assessments of the maturity of a project's or program's critical technologies are also best practices…." The GAO states, "some experts have been concerned that applying the same set of practices to these more

[22] DoDI 5000.02, "Operation of the Defense Acquisition System," December 8, 2008. During the engineering and manufacturing development phase of the KC-46A Tanker Modernization program, the DoD revised DoDI 5000.02 multiple times, including in 2013 and 2015. Ultimately, the DoD restructured the acquisition process in January 2020 and issued DoDI 5000.02, "Operation of the Adaptive Acquisition Framework," January 23, 2020. DoDI 5000.02 still does not require program offices to revalidate changes to critical technologies or technology maturity for major defense acquisition programs during the engineering and manufacturing development phase.

[23] GAO Report No. GAO-16-410G, "Technology Readiness Assessment Guide: Best Practices for Evaluating the Readiness of Technology for Use in Acquisition Programs and Projects," August 2016—subsequently updated and reissued as GAO Report No. GAO-20-48G in January 2020. The GAO developed this TRA guide to: (1) describe generally accepted best practices for conducting effective evaluations of technology developed for systems or acquisition programs; and (2) provide program managers, technology developers, and governance bodies with the tools they need to more effectively mature technology, determine its readiness, and manage and mitigate risk.

frequent assessments might make them too time consuming and cost prohibitive and ultimately dissuade technology and program managers from conducting them." However, the GAO states that these program self-assessments (referred to as knowledge-building technology readiness assessments) could be conducted by or for a narrow audience—for instance, the program manager or systems engineers—to assess the progress in achieving technical maturity for a specific technology or group of technologies. Additionally, the GAO states that organizations conducting tailored TRAs in periods between decision points as knowledge-building exercises can put program managers and technology developers in a better position to gauge progress, monitor and manage technology maturity, and identify and manage risks before they become more costly.

Immature Technologies Are a Systemic Cause of Problems in DoD Acquisition Programs

According to the GAO's TRA guide, the GAO found that, in many DoD acquisition programs, cost growth and schedule delays resulted from overly optimistic assumptions about technology maturity. Additionally, the GAO stated that during product development, TRAs are important inputs into systems engineering events, such as a program's critical design review, and can expose knowledge gaps. If a system's critical technologies are not mature and have not at least been demonstrated in a relevant environment at the point of the program's critical design review, then the program may not have a solid technical basis on which to develop its design.

According to several prior DoD OIG and GAO reports, technology maturity problems occurred in other DoD programs. The following examples are of DoD acquisition program failures where program offices used immature technologies and failed to demonstrate those immature technologies in a relevant environment.

Ford Class Aircraft Carrier Advanced Arresting Gear

DoD OIG Report No. DODIG-2016-107 found that ten years after the program entered the engineering and manufacturing development phase, the Navy was not able to prove the capability or safety of the system to a level that would permit actual testing of the system on an aircraft carrier because of hardware failures and software challenges. This occurred because the Navy pursued a technological solution for its Ford-class carriers that was not sufficiently mature for the planned use, resulting in hardware failures to mechanical and electrical components, and software modifications to accommodate these failures.[24]

[24] DODIG-2016-107, "Advanced Arresting Gear Program Exceeded Cost and Schedule Baselines," July 5, 2016.

As a result, the advanced arresting gear system required significant redesign of mechanical and electrical components to meet system requirements, which delayed developmental testing and contributed to research, development, test, and evaluation costs increasing $571.5 million from the 2005 Acquisition Program Baseline.

National Polar-Orbiting Operational Environmental Satellite System

GAO Report No. GAO-07-96 found that costs for DoD space acquisitions have been consistently underestimated over the past several decades, sometimes by billions of dollars. In 2006, the GAO showed that cost growth in DoD space programs was largely caused by initiating programs before determining whether requirements were achievable. On the National Polar-orbiting Operational Environmental Satellite System program, only 1 of 14 critical technologies was mature at program initiation, and 1 technology was found to be less mature after the contractor conducted more verification testing. The combination of optimistic cost estimates with immature technology resulted in cost increases and schedule delays.

U.S. Army Crusader

GAO Report No. GAO-02-201 found that the Army identified requirements for the Crusader, a lighter and more deployable advanced field artillery system, to replace the Paladin system in 2000. In 2002, the GAO found that the Army had overestimated the maturity of critical technologies and risked cost overruns, schedule delays, and performance shortfalls by prematurely committing the program to product development. The GAO stated that the DoD viewed the Army's long time experience with certain technologies within the program as one reason for the Army's failure to identify all critical technologies. The GAO recommended that the Army further mature the Crusader's technologies before committing to product development and assess the projected capabilities and fielding schedules for future combat systems as part of the Crusader's milestone decision for beginning product development.

Columbia Class Submarine

GAO Report No. GAO-18-158 found that the Navy conducted the 2015 Columbia class TRA in accordance with a DoD-approved plan; however, it did not follow best practices for identifying all critical technology elements, resulting in an underrepresentation of the technical risk facing the program. Specifically, the TRA only identified two critical technology elements, but the GAO identified four additional critical technology elements. The GAO determined that the Columbia class TRA did not identify all appropriate critical technology elements

because the Navy used a more restrictive definition of a critical technology element than that recommended in the GAO best practices guide. The GAO guide states that reused existing technologies can be critical if they are used in a different form, fit, or function. The GAO concluded that, given the risks facing the program and the significance of potential delays or cost growth, this program warranted increased scrutiny of its critical technologies, several of which were immature.

Technology Maturation Plans Are Necessary for Critical Technologies That Are Less Mature Than Required

According to the GAO's TRA guide, it is important for program managers to develop a plan for maturing critical technologies that are rated at a lower technology readiness level than expected. After completion of the TRA, program managers should provide the appropriate information for maturing new technology in other key planning and analytical documents, such as technology maturation plans and risk management plans.

Technology maturation plans establish a road map for maturing technologies to a designated or higher technology readiness level. According to the GAO's TRA guide, a technology maturation plan is a "management planning tool that lays out the steps, actions, and resources needed for maturing critical technologies that have been assessed as less mature than desired or are lagging in maturity compared to other critical technologies."

Technology maturation plans are also useful as key reference documents at program milestones to verify that a program has made adequate progress in closing the maturity gaps. Programs should update technology maturation plans as progress is made, new information is discovered, or as conditions that materially affect the plans occur. If DoD acquisition policy required major defense acquisition programs to use technology maturation plans to ensure that critical technologies are matured to the required technology readiness levels, then KC-46 Program Office officials may have taken additional action to develop the KC-46A tanker refueling boom critical technologies before entering production—potentially minimizing the costly redesign efforts and delayed delivery of the modernized tankers.

The KC-46 Program Office Did Not Verify Full Functionality of the Refueling Boom During Flight Testing

The KC-46 Program Office did not verify full functionality of the KC-46A tanker refueling boom in accordance with the program's TEMP when it performed flight testing of the KC-46A tanker refueling boom and Air Force receiver aircraft, including for the A-10, C-17, and F-16 in 2016.[25]

In support of Milestone C, the TEMP required the KC-46A tanker and receiver aircraft flight tests at low, medium, and high altitudes; low and high airspeeds; low, medium, and heavy gross weights; and middle center of gravity to most critical center of gravity.[26] Specifically, the Milestone C entrance criteria in the TEMP required the KC-46A tanker to aerially rendezvous, contact, and transfer fuel to light-slow, heavy, and light-fast receiver aircraft. The TEMP identified these receiver aircraft as the A-10, C-17, and F-16, respectively.

According to the DoDI 5000.02 in effect at the time of Milestone C flight testing, the purpose of developmental test and evaluation activities was to evaluate the ability of the system to provide effective combat capability, including the verification of the ability of the system to achieve key performance parameters and key system attributes.[27] For example, a key performance parameter for the KC-46A tanker is that it must be able to accomplish aerial refueling of receiver aircraft in accordance with the applicable aerial refueling standards using established procedures and refueling airspeeds with no modifications to existing receiver aerial refueling equipment. Additionally, the DoDI 5000.02 required completion of developmental test and evaluation activities consistent with the TEMP. Successful completion of adequate testing with production representative equipment is normally the primary basis for entering the post Milestone C production and deployment phase.

[25] The TEMP describes an acquisition program's planned test and evaluation activities over a program's life-cycle and identifies evaluation criteria for the testers. The KC-46A Tanker Modernization Program released a post Milestone B TEMP, dated June 29, 2012, and a Milestone C TEMP, dated October 2015.

[26] Aircraft gross weight is the total aircraft weight at any moment during flight or ground operation. Low, medium, and heavy gross weights are aircraft dependent and established by the aircraft manufacturer. Total gross weight varies by fuel and cargo loading for a heavy receiver or fuel and weapons loading for a fighter or attack receiver. The center of gravity is the balance point of the aircraft. The most critical center of gravity for a heavy receiver is the most stressing forward or backward point for aircraft center of gravity. The most critical center of gravity for a light-slow and light-fast receiver is asymmetric wing loading.

[27] Key performance parameters are core performance parameters that capture the essential functionality of the system and should represent the major cost drivers of the program. Key performance parameters are so critical that a failure to meet a key performance threshold brings the military utility of the system into question and could result in a reevaluation of the program and potentially program cancellation. Key system attributes are attributes or characteristics considered essential to achieve the identified key performance parameters.

The Defense Acquisition Guidebook states that one set of developmental tests can result in multiple developmental evaluations. However, Air Force Instruction 99-103 states that test planners should carefully review the use of small test sample quantities. After thorough analysis, test planners may decide some test activities should not be combined.[28]

During KC-46A tanker developmental test and evaluation, KC-46 Program Office officials used the same flight tests to achieve the Milestone C entrance criteria and to resolve the refueling boom high axial load problem that occurred just prior to Milestone C. In 2014, representatives from the KC-46 Program Office and the Office of the DASD(DT&E) reached an agreement on planned flight tests for Milestone C. This testing did not include all conditions stated in the TEMP. Specifically, this reduced flight testing included light-slow, heavy, and light-fast receiver aircraft and departed from the TEMP by testing:

- one light-slow receiver aircraft at only one airspeed and altitude combination;
- one light-fast receiver aircraft at two different airspeeds, but only one altitude; and
- one heavy receiver aircraft at only two airspeeds and two altitudes.

In 2016, when pilots conducted the Milestone C flight tests, KC-46 Program Office officials further reduced the 2014 flight test plans by testing:

- one light-slow receiver aircraft (A-10) at only one airspeed and altitude combination in a clean wing configuration.[29] According to a KC-46 Program Office engineer, flight test personnel and pilots tested the light-slow receiver aircraft at nominal gross weight and nominal center of gravity. We found no evidence of testing at aircraft heavy gross weight or the most stressing point for aircraft center of gravity, as required by the TEMP;[30]

[28] Air Force Instruction 99-103, "Capabilities-Based Test and Evaluation," October 16, 2013.

[29] A clean wing configuration is an optimum wing configuration to minimize aerodynamic drag on an aircraft that is operationally representative. A clean wing configuration typically does not contain external fuel tanks or weapons, unless such equipment is considered part of the aircraft nominal configuration.

[30] Nominal refers to a flight test condition (for example, gross weight or center of gravity) that is within expected boundaries for a receiver aircraft. However, nominal is not a critical or stressing condition.

Figure 3. A-10 Receiver Aircraft Refueling
Source: The Air Force.

- one light-fast receiver aircraft (F-16) at only one airspeed and altitude combination in a clean wing configuration. According to a KC-46 Program Office engineer, flight test personnel and pilots tested the light-fast receiver aircraft at nominal gross weight and nominal center of gravity. We found no evidence of testing at aircraft heavy gross weight or the most stressing point for aircraft center of gravity, as required by the TEMP; and

Figure 4. F-16 Receiver Aircraft Refueling
Source: The Air Force.

Figure 5. C-17 Receiver Aircraft Refueling
Source: The Air Force.

- one heavy receiver aircraft (C-17) at only one airspeed and altitude combination in a medium gross weight configuration. According to a KC-46 Program Office engineer, flight test personnel and pilots tested the heavy receiver aircraft at nominal center of gravity. We found no evidence the flight test personnel and pilots tested the heavy receiver aircraft at low or heavy gross weights or the most critical stressing point for aircraft center of gravity, as required by the TEMP.

Additionally, the KC-46 Program Office officials used the results of these reduced flight tests to demonstrate a solution to the refueling boom high axial load problem identified during Milestone C flight tests. After successfully completing the reduced flight tests, KC-46 Program Office officials prematurely considered the refueling boom high axial load problem resolved. However, this reduced flight testing did not fully demonstrate that the KC-46A tanker was capable of refueling light-slow, heavy, and light-fast receiver aircraft in accordance with the TEMP for Milestone C. During these flight tests conducted prior to Milestone C, the stressing conditions, under which the stiff boom problem could potentially occur, were not tested.

According to a KC-46 Program Office engineer, since approximately 2000, flight tests for light-slow and light-fast receiver aircraft with the KC-10, KC-135, Royal Australian Air Force KC-30, and Italian Air Force KC-767 tankers historically included testing the light-slow and light-fast receiver aircraft in clean wing

and heavy gross weight (combat representative with external fuel tanks and weapons in place), and critical center of gravity (asymmetric wing loading) configurations.[31] Pilots flew these tanker flight tests throughout the receiver aircraft aerial refueling flight envelopes to ensure a wide spectrum of operational conditions was assessed.[32] Additionally, according to a KC-46 Program Office engineer, since approximately 2000, flight tests for heavy receiver aircraft with the KC-10, KC-135, and Royal Australian Air Force KC-30 historically included testing the heavy receiver aircraft at a heavy gross weight with forward center of gravity configuration and a light gross weight with rearward center of gravity configuration throughout the allowable ranges of airspeed and altitude. Furthermore, the KC-46 Program Office engineer stated that in addition to varying gross weight and center of gravity conditions for receiver aircraft, these flight tests also historically included the stressing gross weight and center of gravity conditions for the tankers themselves. According to the KC-46 Program Office engineer, the KC-46A tanker was not tested at these stressing conditions during Milestone C testing in accordance with the TEMP.

If KC-46 Program Office officials had conducted flight testing in accordance with the TEMP, they would have had greater assurances that the KC-46A tanker complied with its aerial refueling performance requirements, including resolution of the refueling boom high axial load problem. Therefore, the KC-46 Program Office and the Office of the DASD(DT&E) officials missed an opportunity to initiate corrective action to resolve the KC-46A tanker aerial refueling boom high axial load problem during receiver aircraft tests prior to Milestone C in 2016.

Consequently, in 2018 the KC-46A tanker aerial refueling boom high axial load problem resurfaced during receiver aircraft certification testing that was more comprehensive than testing conducted prior to Milestone C. This caused Air Force officials to issue a Category I performance deficiency for the KC-46A tanker in 2018. According to Air Force Instruction 99-103, Category I deficiencies are those that may cause death, severe injury, or severe occupational illness; may cause loss or major damage to a weapon system; critically restrict the combat readiness capabilities of the using organization; or result in a production line stoppage.

Ultimately, the KC-46A tanker boom deficiency led an official from the Office of the Under Secretary of Defense for Research and Engineering to write an August 6, 2019, initial operational test readiness memorandum, stating, “testing

[31] Asymmetric wing loading is a varying configuration of equipment or weapons across an aircraft’s wings such that weight and aerodynamic drag are unevenly distributed, resulting in a change in aircraft center of gravity. Asymmetric wing loading is the most critical center of gravity configuration for light-slow and light-fast receiver aircraft.

[32] An aerial refueling flight envelope is the authorized range of airspeed and altitude combinations for safe operation of a specific tanker and receiver aircraft.

demonstrated that the stiff boom prevents the KC-46A from safely refueling a loaded A-10 close support aircraft and poses serious risks to other receivers." Moreover, the official from the office of the Under Secretary wrote that the "[KC-46A aerial refueling] system [is] prohibited from refueling the A-10." As of November 2020, the stiff boom problem still existed and the KC-46A tanker was still prohibited from refueling the A-10 and several variants of the C-130 receiver aircraft.

The KC-46 Program Office Reduced the Scope of Flight Testing for Initial Refueling Boom Verification

Officials from the KC-46 Program Office reduced the scope of flight testing for the initial refueling boom verification from what was planned in the TEMP. Specifically, KC-46 Program Office officials decided, and Office of the DASD(DT&E) officials accepted, in 2014 that reduced flight testing was sufficient and acceptable for initial receiver aircraft certification to evaluate the performance of the KC-46A tanker in support of a program Milestone C decision in 2016. Despite encountering flight test failures in January 2016 that required Boeing engineers to redesign the refueling boom, the KC-46 Program Office officials did not change their decision to perform reduced flight testing prior to the Milestone C decision. Furthermore, when the KC-46 Program Office officials conducted the Milestone C flight tests in 2016, they further reduced the flight tests from the 2014 agreement.

KC-46 Program Office officials were not able to provide us with a rationale showing how these reduced flight tests would sufficiently demonstrate receiver aircraft performance at Milestone C. Consequently, we concluded that eliminating the most stressing aircraft test conditions or deferring these tests prevented KC-46 Program Office officials from determining the full impact of the refueling boom high axial load problem at Milestone C.

The DASD(DT&E) Established a Plan for Using Scientific Test and Analysis Techniques in Test and Evaluation in 2012

In January 2012, the DASD(DT&E) established an Implementation Plan for Scientific Test and Analysis Techniques in Test and Evaluation to provide guidance for the development and implementation of DoD-wide scientific-based test and evaluation planning, execution, and analysis capability. According to this implementation plan, the use of scientific test and analysis techniques provides rigorous and defensible test and evaluation strategies and results, and helps program officials to make better decisions based on acceptable risk levels.

The DoD's Implementation Plan for Scientific Test and Analysis Techniques in Test and Evaluation was to be implemented in three phases. The first phase, the "initiation phase," was to facilitate the transition to scientifically-based test and analysis by FY 2014. The second phase, the "expanded phase," would expand the depth of programs that use scientific approaches to testing by FY 2016. Finally, the third phase, the "institutionalize phase," would complete the implementation of the scientific test and analysis techniques in test and evaluation by FY 2018.

Accordingly, the January 2015 version of DoDI 5000.02, in effect at Milestone C of the KC-46A Tanker Modernization program, stated that program managers will use scientific test and analysis techniques to design an effective test program that will provide the data used to evaluate the performance of a system. Additionally, the January 2015 version of DoDI 5000.02, required program officials to perform test and evaluation activities consistent with the TEMP. However, this DoDI 5000.02 version did not require the use of scientific test and analysis techniques to support decisions to deviate from TEMP requirements. Additionally, the current versions of DoDI 5000.02, issued in January 2020, DoDI 5000.85, issued in August 2020, and DoDI 5000.89, issued in November 2020, do not require the use of scientific test and analysis techniques to support either the development of the TEMP or decisions to deviate from TEMP requirements.[33]

The Air Force Issued $100 Million in Contract Modifications for the Redesign of the Refueling Boom With Additional Schedule Impacts Expected

The Air Force issued $100 million in contract modifications to redesign the refueling boom for the KC-46A tanker. Following the Milestone C decision and after additional flight testing in 2018, flight tests demonstrated that refueling boom performance remained a problem during in-flight refueling of the A-10, C-17, and F-16 receiver aircraft. Specifically, the KC-46A tankers that Boeing had already delivered to the Air Force could not refuel the A-10 or several variants of the C-130 receiver aircraft, and Air Force officials imposed operational limitations allowing the B-52, C-17, F-15, F-16, F-35A, HC/MC-130J, KC-10, KC-46A, and KC-135 receiver aircraft to aerially refuel only under limited flight conditions. As of October 2020, Boeing delivered 38 of 179 total KC-46A tankers to the Air Force.

As a result of the identified refueling boom problems, the Air Force issued contract modifications to Boeing in August 2019 and March 2020 for the redesign of the KC-46A tanker refueling boom. The Air Force finalized these contract modifications in September 2020, valued at $100 million. Had KC-46 Program

[33] DoDI 5000.89, "Test and Evaluation," November 19, 2020.

Office officials effectively managed the development and testing of the refueling boom for the KC-46A tanker, the Air Force would not have had to spend an additional $100 million for the redesign of the refueling boom to achieve the required performance. Furthermore, component retrofit work for the delivered KC-46A tankers is not estimated to begin until January 2024 and will result in additional undetermined costs, as well as approximately a 5-year delayed delivery of the first KC-46A tankers with full mission-capable refueling booms. This delay limits the DoD's use of the KC-46A tanker for its intended refueling missions. Additionally, the Commander of United States Transportation Command identified the aerial refueling fleet as the most stressed of air mobility forces and stated that any delay of the KC-46 production puts the Joint Force's ability to effectively execute war plans at risk. Finally, Congress included minimum inventory requirements and prohibitions on the retirement of legacy KC-10 and KC-135 refueling tankers in the FY 2021 National Defense Authorization Act.

Recommendations, Management Comments, and Our Response

Revised and Additional Recommendations

As a result of management comments on the draft report, we revised Recommendations 1.c and 1.d and added Recommendations 1.e and 1.f, to clarify the actions needed to improve the initial development of the Test and Evaluation Master Plan and subsequent elimination, deferral, or modification of planned tests that were originally documented in the Test and Evaluation Master Plan.

Recommendation 1

We recommend that the Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment revise DoD Instruction 5000.85 and its supplementary acquisition policy issuances to require program managers of major defense acquisition programs to:

a. Conduct knowledge-building technology readiness assessments throughout the DoD acquisition life cycle, including at preliminary design review, critical design review, and Milestone C, at a minimum.

Under Secretary of Defense for Research and Engineering Comments

The Director of Developmental Test, Evaluation, and Assessments, responding for the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment, agreed with the recommendation and stated that this requirement already exists in sections 2366b and 2448b, title 10, United States Code (10 U.S.C. §§ 2366b and 2448b); DoDI 5000.85; and DoDI 5000.88.

Our Response

Although the Director agreed, his comments only partially addressed our recommendation. Specifically, the Director stated that 10 U.S.C. §§ 2366b and 2448b, DoDI 5000.85, and DoDI 5000.88 require MDAPs to conduct independent technical risk assessments prior to Milestone A, Milestone B, and before any decision to enter low rate initial production, full rate production, or at any other time considered appropriate by the Secretary of Defense. However, neither the law nor the policies cited specifically require program managers of MDAPs to conduct independent technical risk assessments or technology readiness assessments at preliminary design review, critical design review, or Milestone C, as specified in our recommendation. Preliminary design review and critical design review occur after Milestone B and before Milestone C in the engineering manufacturing and development phase. Officials from the KC-46 Program Office did not revalidate changes to KC-46A refueling boom critical technologies or technology maturity at any point during the engineering and manufacturing development phase, since revalidations were not required by DoD policy. Specifically, requiring program managers to conduct knowledge-building technology readiness assessments during the engineering and manufacturing development phase, including at preliminary design review and critical design review, as well as at Milestone C, will put program managers and technology developers in a better position to gauge progress, monitor and manage technology maturity, and identify and manage risks before they become more costly. Therefore, the recommendation is unresolved. We request that the Director describe the specific actions that the USD(R&E), in coordination with the USD(A&S), will take to require program managers of MDAPs to conduct knowledge-building technology readiness assessments at preliminary design review, critical design review, and Milestone C, at a minimum.

b. Develop and execute technology maturation plans for critical technologies that have not been demonstrated in a relevant environment, as determined by a knowledge-building or statutory technology readiness assessment.

Under Secretary of Defense for Research and Engineering Comments

The Director of Developmental Test, Evaluation, and Assessments, responding for the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment, agreed with the recommendation and stated that this requirement already exists in sections 2366a, 2366b, and 2448b, title 10, United States Code (10 U.S.C. §§ 2366a, 2366b, and 2448b), DoDI 5000.85, subchapter II of Chapter 144B of 10 U.S.C., and DoDI 5000.88.

Our Response

Although the Director agreed, his comments only partially addressed our recommendation. Specifically, the Director stated that 10 U.S.C. §§ 2366a, 2366b, and 2448b; DoDI 5000.85; and DoDI 5000.88 require MDAPs to conduct independent technical risk assessments at Milestone A, Milestone B, and before any decision to enter low rate initial production, full rate production, or at any other time considered appropriate by the Secretary of Defense. However, neither the law nor the policies cited specifically require MDAPs to develop and execute technology maturation plans for critical technologies that have not been demonstrated in a relevant environment. Although DoDI 5000.85 requires critical technologies to be sufficiently matured and demonstrated in a relevant environment separate from the program; and the MDA to have an effective plan for adoption or insertion of these critical technologies by the relevant program, this language only applies to Milestone A. Milestone A is entry into the technology maturation and risk reduction phase of the DoD acquisition cycle, and these requirements do not apply to other phases of the acquisition process (for example, during the engineering and manufacturing development phase). Therefore, the recommendation is unresolved. We request that the Director describe the specific actions that the USD(R&E), in coordination with the USD(A&S), will take to require program managers of MDAPs to develop and execute technology maturation plans for critical technologies that have not been demonstrated in a relevant environment after Milestone A, for example during the engineering and manufacturing development phase of the DoD acquisition cycle.

c. Use scientific test and analysis techniques to the maximum extent possible to develop the Test and Evaluation Master Plan.

d. Use scientific test and analysis techniques to the maximum extent possible to justify the elimination, deferral, or modification of planned tests that were originally documented in the Test and Evaluation Master Plan.

e. Include the most critical or stressing test conditions in the Test and Evaluation Master Plan for any tests where the use of scientific test and analysis techniques is impractical or not applicable when developing the Test and Evaluation Master Plan.

f. Include the most critical or stressing test conditions in revised test plans when proposing elimination, deferral, or modification of planned tests that were originally documented in the Test and Evaluation Master Plan.

Under Secretary of Defense for Research and Engineering Comments

The Director of Developmental Test, Evaluation, and Assessments, responding for the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment, partially agreed with Recommendation 1.c and stated that DoDI 5000.89 already requires programs to "identify how scientific test and analysis tools will be used to design an effective and efficient test program that will produce the required data to characterize system behavior and combat mission capability across an appropriately selected set of factors and conditions." The Director stated that scientific test and analysis techniques continue to be a proven valuable resource for test programs; however, he also stated that the statistical methods used with scientific test and analysis techniques do not universally apply to all kinds or aspects of developmental test programs (including, for example, airworthiness and other certification testing, in addition to most system verification tests). Furthermore, the Director stated that documenting the use of scientific test and analysis techniques in the Test and Evaluation Master Plan, in accordance with DoDI 5000.89, meets the intent of the draft recommendation without requiring the use of statistical methods when it does not add value to a test program.

In addition, the Director partially agreed with draft Recommendation 1.d and stated that the elimination, deferral, and modification of planned tests are a routine part of developmental test execution. The Director stated that the use of scientific test and analysis techniques is valuable for developing test strategies, evaluating test results, and modifying test plans, but is not always necessary for routine modifications to detailed test planning. The Director stated that as developmental testing builds knowledge about a system, the test team routinely modifies the early test plans. For example, the test team may eliminate unnecessary tests or add tests to explore the discovery of issues and then test the solution.

Our Response

Comments from the Director partially addressed Recommendations 1.c and 1.d. We agree that the statistical methods used with scientific test and analysis techniques do not universally apply to all kinds or aspects of developmental test programs. However, DoD policy does not require the use of scientific test and analysis techniques to develop the Test and Evaluation Master Plan; DoD policy only requires program managers to describe their planned use of scientific test and analysis techniques in the Test and Evaluation Master Plan. If major acquisition programs do not use scientific test and analysis techniques to develop the Test and Evaluation Master Plan, they must ensure that the Test and Evaluation Master Plan requires testing of the most critical or stressing test conditions.

We agree that elimination, deferral, and modification of planned tests from the program's Test and Evaluation Master Plan may be a part of developmental test execution and, as developmental testing builds knowledge about a system, the test team may decide to modify the early test plans. However, we do not agree that all of these types of changes can be considered routine. Scientific test and analysis techniques should be used to the maximum extent possible for developing test strategies and modifying test plans that depart from the program's Test and Evaluation Master Plan. Where the use of scientific test and analysis techniques is impractical in guiding decisions to eliminate, defer, or modify planned tests from the program's Test and Evaluation Master Plan, major acquisition programs must ensure that the most critical or stressing test conditions are not eliminated from the Test and Evaluation Master Plan. For example, with the KC-46A refueling boom, KC-46 Program Office officials decided not to conduct Milestone C flight tests with the Test and Evaluation Master Plan's most critical or stressing conditions for gross weight and center of gravity as originally planned. This reduced flight testing did not include the stressing conditions under which the refueling boom problem could potentially occur. Consequently, the KC-46 Program Office officials missed an opportunity to initiate corrective action and resolve the KC-46A tanker aerial refueling boom problem during tests prior to Milestone C.

Therefore, Recommendations 1.c and 1.d are unresolved. We request that the Director describe the specific actions that the USD(R&E), in coordination with the USD(A&S), will take to ensure scientific test and analysis techniques are used to the maximum extent possible to develop the Test and Evaluation Master Plan and to justify the elimination, deferral, or modification of planned tests that were originally documented in the Test and Evaluation Master Plan.

Additionally, Recommendations 1.e, and 1.f are unresolved. We request that the Director describe the specific actions that the USD(R&E), in coordination with the USD(A&S), will take to require program managers of MDAPs to include the most critical or stressing test conditions in the development and modification of the Test and Evaluation Master Plan where the use of scientific test and analysis techniques is not practical.

Appendix A

Scope and Methodology

We conducted this evaluation from September 2019 through March 2021 in accordance with the "Quality Standards for Inspection and Evaluation," published in January 2012 by the Council of Inspectors General on Integrity and Efficiency. Those standards require that we adequately plan the evaluation to ensure that objectives are met and that we perform the evaluation to obtain sufficient, competent, and relevant evidence to support the findings, conclusions, and recommendations. We believe that the evidence obtained was sufficient, competent, and relevant to lead a reasonable person to sustain the findings, conclusions, and recommendations.

We evaluated the Air Force requirements and systems engineering processes used in the design and development of the KC-46A tanker refueling boom. The evaluation was self-initiated to:

- identify problems with the DoD and Air Force systems engineering processes used in the design and development of the KC-46A tanker refueling boom that may apply to all DoD acquisition programs; and
- provide recommendations to reduce the possibility of those problems occurring in new DoD weapons systems.

The scope of our evaluation included a review of the KC-46A tanker refueling boom development during the engineering and manufacturing development and production and deployment phases of the acquisition life cycle. Specifically, our evaluation covered the KC-46A Tanker Modernization program through the following events and phases of the DoD acquisition cycle: pre-Milestone B from 2008 through 2010, Milestone B in 2011, the engineering manufacturing and development phase from 2011 through Milestone C approval in 2016, and the production and deployment phase from 2016 through entry into initial operational test and evaluation in 2019. Additionally, the scope of our evaluation included interviews with representatives of the KC-46 Program Office, Boeing, and the following KC-46A Tanker Modernization program stakeholders.

- Air Force Deputy Chief of Staff for Strategic Plans and Requirements (A5RM)
- Headquarters Air Force Test and Evaluation
- Office of the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation
- The Air Force Life Cycle Management Center, Crew Systems Branch

Based on interviews of KC-46 Program Office personnel, KC-46A Tanker Modernization program stakeholders, and the prime contractor (The Boeing Company), we narrowed the evaluation down to specific systems engineering processes in which missteps could have occurred that contributed to the problems with the development of the KC-46A tanker refueling boom. The systems engineering processes we focused on included those related to technology readiness assessment, requirements development, design reviews, and system verification. We analyzed documentary and testimonial evidence for KC-46A Tanker Modernization program compliance with applicable DoD and Air Force policy, instruction, and guidance, in addition to program contractual documentation.

We analyzed the following documentary evidence.

- KC-X Capability Development Document, KC-X Technology Readiness Assessment Report, KC-X System Requirements Document, and the KC-46A System Engineering Plan, Systems requirements review, preliminary design review, and critical design review documentation[34]
- The statement of work for engineering, manufacturing, and development for the KC-X Tanker
- Test and Evaluation Master Plan for the KC-46 Program, KC-46A tanker flight test reports and data
- E-mail correspondence regarding technology readiness assessment, requirement generation, and verification tests

We obtained testimonial evidence from KC-46A Tanker Modernization program stakeholders through virtual and in-person interviews. Specifically, we met with the following stakeholders to identify key systems engineering and design decisions that led to the KC-46A tanker refueling boom performance deficiencies.

- Air Force Deputy Chief of Staff for Strategic Plans and Requirements (A5RM)
- Headquarters Air Force Test and Evaluation
- Office of the Deputy Director for Developmental Test, Evaluation, and Prototyping
- KC-46 Program Office at the Air Force Life Cycle Management Center (AFLCMC)
- Air Force Life Cycle Management Center, Crew Systems Branch

[34] Program documentation contained the aircraft designation "KC-X" before the new tanker was designated as the KC-46A.

In addition, we met with officials from The Boeing Company in Everett, Washington, to obtain an understanding of their systems engineering processes on the KC-46A Tanker Modernization program and discuss their interactions with DoD and Air Force officials.

Criteria:

We used the following applicable law, policy, and guidance.

- Section 2366b, title 10, United States Code, "Certification Requirements for Major Defense Acquisition Programs," 2010
- DoD Instruction 5000.02, "Operation of the Defense Acquisition System," December 8, 2008
- DoD Instruction 5000.02, "Operation of the Defense Acquisition System," January 7, 2015
- Air Force Instruction 99-103, "Capabilities-Based Test and Evaluation," October 16, 2013
- Defense Acquisition Guidebook
- GAO Technology Readiness Assessment Guide, GAO-16-410G, August 2016
- GAO Technology Readiness Assessment Guide, GAO-20-48G, August 2020
- DoD Technology Readiness Assessment (TRA) Deskbook, July 2009

Use of Computer-Processed Data

We did not use computer-processed data to perform this evaluation.

Prior Coverage

During the last 5 years, the Government Accountability Office (GAO) published three reports discussing the KC-46A Tanker Modernization program.

Unrestricted GAO reports can be accessed at http://www.gao.gov.

GAO

Report No. GAO-19-480, "KC-46 Tanker Modernization: Aircraft Delivery Has Begun, but Deficiencies Could Affect Operations and Will Take Time to Correct," June 2019

> The Air Force contracted with Boeing to turn commercial aircraft into aerial refueling tankers. The contract is an infrequently-used type (fixed-price [firm target]) intended to protect the Government from cost overruns and incentivize the contractor to keep costs down. After a nearly 3-year delay, the Air Force accepted the first plane in January 2019—with critical defects that don't meet

contract standards. The Air Force is withholding the remaining 20 percent of the price until the defects are addressed. Now that some of the planes are arriving, GAO recommended that the Department of Defense share lessons learned from this contracting approach with other DoD acquisition programs.

Report No. GAO-18-353, "KC-46 Tanker Modernization: Program Cost Is Stable, but Schedule May Be Further Delayed," April 2018

Under the Air Force's KC-46 modernization program, commercial aircraft are being converted by Boeing into aerial refueling tankers. The program is one of the Air Force's highest acquisition priorities and will replace a third of the aging fleet. GAO found that the program, in its seventh year, was meeting its estimated acquisition cost. However, the program office projected that Boeing would not deliver the first 18 fully capable aircraft until May 2019—21 months later than initially planned.

Report No. GAO-17-370, "KC-46 Tanker Modernization: Delivery of First Fully Capable Aircraft Has Been Delayed over One Year and Additional Delays Are Possible," March 2017

The Air Force's KC-46 modernization program—initiated to replace a third of its aging aerial refueling fleet—was meeting its cost and performance targets. With fewer engineering changes than expected, the program's estimated total acquisition cost decreased about $7.3 billion, or 14 percent, since its initial estimate. However, the project remained behind schedule. Boeing—the prime contractor—planned to deliver the first 18 fully capable aircraft to the Air Force by October 2018, 14 months later than initially planned. Potential delays in completing flight tests may further delay the delivery of aircraft.

Appendix B

Timeline of Major Events in the KC-46A Tanker Modernization Program Related to the Refueling Boom Problems

- February 2011 – Technology Readiness Assessment report issued, Milestone B approval, contract award, and entry into the engineering and manufacturing development phase
- May 2012 – Preliminary Design Review
- August 2013 – Critical Design Review
- December 2014 – KC-46 Program Office and the Office of the DASD(DT&E) agree to reduce the scope of flight tests in support of Milestone C
- January through July 2016 – Flight testing in support of Milestone C
- August 2016 – Milestone C approval and entry into the production and deployment phase
- August 2017 – Original delivery date for the first 18 KC-46As
- April through July 2018 – Flight testing in support of receiver aircraft certification
- September 2018 – Air Force issued Category 1 deficiency for stiff boom problem
- December 2018 – KC-46 Program Office established new technical requirements for the boom redesign
- January 2019 – First KC-46A tanker delivery
- August 2019 – USD(R&E) issued the initial operational test readiness memorandum for the KC-46A
- August 2019 – Air Force issued contract modification to support KC-46A boom telescope redesign effort
- March 2020 – Air Force issued contract modification to support KC-46A boom telescope redesign effort
- September 2020 – The Air Force issued a contract modification definitizing the value of two modifications at $100 million, which were issued to support the redesign of the KC-46A refueling tanker
- October 2020 – 38 KC-46A tankers delivered to date

Management Comments

Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3030 DEFENSE PENTAGON
WASHINGTON, DC 20301-3030

RESEARCH
AND ENGINEERING

MEMORANDUM FOR INSPECTOR GENERAL OF THE DEPARTMENT OF DEFENSE

SUBJECT: Evaluation of the Air Force Systems Engineering Processes Used in the Development of the Refueling Boom for the KC-46A Tanker

Thank you for the opportunity to respond to the subject draft report. The refueling boom is a critical component of the aerial refueling system for the KC-46A tanker. I have attached the Office of the Under Secretary of Defense for Research and Engineering response to the recommendations in the draft report. This response was coordinated with the Office of the Under Secretary of Defense for Acquisition and Sustainment.

My point of contact is [redacted]

COLLINS.CHRISTO[redacted]
PHER.CLAY.[redacted]

Digitally signed by COLLINS.CHRISTOPHER.CLAY.[redacted]
Date: 2021.03.26 13:53:18 -04'00'

Christopher C. Collins
Director, Developmental Test, Evaluation, and Assessments

Attachment:
As stated

Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment (cont'd)

Final Report Reference

USD(R&E) Response to DODIG Recommendations on the KC-46A Boom Project No. D2019-DEV0SR-0199.000

RECOMMENDATION 1. We recommend that the Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment revise DoD Instruction 5000.85 and its supplementary acquisition policy issuances to require program managers of major defense acquisition programs to:

RECOMMENDATION 1.a. Conduct knowledge-building technology readiness assessments throughout the DoD acquisition life cycle, including at preliminary design review, critical design review, and Milestone C, at a minimum.

USD(R&E) RESPONSE: Concur. USD(R&E) agrees with the general recommendation, however, this requirement already exists in current guidance. Sections 2366b(a)(2) and 2448b(a) of Title 10, United States Code (U.S.C.); Paragraphs 3.6, 3.7, 3.8, 3.11, and 3.14 of DoD Instruction (DoDI) 5000.85; and Paragraph 3.5 of DoDI 5000.88 together already require programs to conduct the reviews and assessments mentioned in this recommendation.

RECOMMENDATION 1.b. Develop and execute technology maturation plans for critical technologies that have not been demonstrated in a relevant environment, as determined by a knowledge-building or statutory technology readiness assessment.

USD(R&E) RESPONSE: Concur. USD(R&E) agrees with the general recommendation, however, this requirement already exists in current guidance. Section 2366b(a)(2) of Title 10, U.S.C., requires that the milestone decision authority "further certifies that the technology in the program has been demonstrated in a relevant environment, as determined by the milestone decision authority on the basis of an independent review and technical risk assessment conducted under section 2448b of this title." Pursuant to Section 2366a(b)(8) of Title 10, U.S.C., Paragraph 3.7.b.(3)(a) of DoDI 5000.85 requires that "The technology must be sufficiently matured and demonstrated in a relevant environment separate from the program, using the prototyping authorities in subchapter II of Chapter 144B of Title 10, U.S.C., or other authorities, as appropriate." Paragraph 3.7.b.(3)(b) of DoDI 5000.85 further requires that "The MDA must have an effective plan for adoption or insertion by the relevant program." Paragraph 3.5.b.(5) of DoDI 5000.88 requires that "Programs will continue to assess and document the technology maturity of all critical technologies consistent with the technology readiness assessment guidance." Such assessments and documentation culminate from technology maturation plans for critical technologies as required by Sections 2366a and 2366b of Title 10, U.S.C., and DoDI 5000.85.

Revised Recommendation 1.c

RECOMMENDATION 1.c. Use scientific test and analysis techniques [STAT] (for example, design of experiments) to develop the Test and Evaluation Master Plan [TEMP].

USD(R&E) RESPONSE: Partially concur. Paragraph 3.4.b.(6) of DoDI 5000.89 already requires programs to "Identify how scientific test and analysis tools will be used to design an effective and efficient test program that will produce the required data to characterize system behavior and combat mission capability across an appropriately selected set of factors and

Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment (cont'd)

Final Report Reference

conditions." The predecessor organization to USD(R&E) sponsored the creation of the STAT organization in 2012 and advocated for its use by test programs. STAT support continues as a proven valuable resource, accumulating an impressive record of helping test programs. However, STAT does not universally apply to all kinds or aspects of developmental test programs. For example, airworthiness and other certification testing must meet discreet performance and safety requirements. The same is true for most system verification tests. Test safety requires a build-up approach, often adjusted in real time, to explore the envelope limits of a system. STAT as a statistical approach or toolbox does not apply in such cases. To require a STAT approach for all test programs would divert limited resources from test planning and execution to justify a deviation from a STAT requirement when STAT would not apply or add value. Documenting STAT use in the TEMP in accordance with DoDI 5000.89 is sufficient to meet the intent of Recommendation 1.c. without requiring the use of STAT when it does not add value to a test program.

Revised Recommendation 1.d

RECOMMENDATION 1.d. Use scientific test and analysis techniques when proposing elimination, deferral, or modification of planned tests that were documented in the Test and Evaluation Master Plan.

USD(R&E) RESPONSE: Partially concur. In addition to the reasoning in response to Recommendation 1.c., elimination, deferral, and modification of planned tests are a routine part of developmental test execution. STAT is a valuable tool for developing test strategies, evaluating test results, and modifying test plans, but is not always necessary for routine modifications to detailed test planning. As developmental testing builds knowledge about a system, the test team routinely modifies the early test plans. For example, the test team may eliminate unnecessary tests or add tests to explore the discovery of issues and then test the solution.

Acronyms and Abbreviations

AFLCMC	Air Force Life Cycle Management Center
DASD(DT&E)	Deputy Assistant Secretary of Defense for Developmental Test and Evaluation
TEMP	Test and Evaluation Master Plan
TRA	Technology Readiness Assessment
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USD(R&E)	Under Secretary of Defense for Research and Engineering

Whistleblower Protection
U.S. Department of Defense

Whistleblower Protection safeguards DoD employees against retaliation for protected disclosures that expose possible fraud, waste, and abuse in Government programs. For more information, please visit the Whistleblower webpage at http://www.dodig.mil/Components/Administrative-Investigations/Whistleblower-Reprisal-Investigations/Whisteblower-Reprisal/ or contact the Whistleblower Protection Coordinator at Whistleblowerprotectioncoordinator@dodig.mil

For more information about DoD OIG reports or activities, please contact us:

Congressional Liaison
703.604.8324

Media Contact
public.affairs@dodig.mil; 703.604.8324

DoD OIG Mailing Lists
www.dodig.mil/Mailing-Lists/

Twitter
www.twitter.com/DoD_IG

DoD Hotline
www.dodig.mil/hotline

DEPARTMENT OF DEFENSE | OFFICE OF INSPECTOR GENERAL

4800 Mark Center Drive
Alexandria, Virginia 22350-1500
www.dodig.mil
DoD Hotline 1.800.424.9098