



April 2014

KC-46 TANKER AIRCRAFT

Program Generally on
Track, but Upcoming
Schedule Remains
Challenging

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GAO Highlights

Highlights of [GAO-14-190](#), a report to congressional committees

Why GAO Did This Study

Aerial refueling allows U.S. military aircraft to fly farther, stay airborne longer, and transport more weapons, equipment, and supplies. Yet the mainstay of the U.S. tanker forces—the KC-135 Stratotanker—is over 50 years old. It is increasingly costly to support and its age-related problems could potentially ground the fleet. As a result, the Air Force initiated the \$51 billion KC-46 program to replace the aerial refueling fleet. The program plans to produce 18 tankers by 2017 and 179 aircraft in total.

The National Defense Authorization Act for Fiscal Year 2012 mandated GAO to annually review the KC-46 program through 2017. This report addresses (1) progress made in 2013 toward cost, schedule, and performance goals, (2) development challenges, if any, and steps to address them, and (3) progress made in manufacturing the aircraft. To do this, GAO reviewed key program documents and discussed development and production plans and results with officials from the KC-46 program office, other defense offices, and the prime contractor, Boeing.

What GAO Recommends

GAO recommends that the Air Force determine the likelihood and potential effect of delays on total development costs, and develop mitigation plans, as needed, related to potential delays. DOD concurred with the recommendation.

View [GAO-14-190](#). For more information, contact Michael J. Sullivan at (202) 512-4841 or sullivanm@gao.gov.

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KC-46 TANKER AIRCRAFT

Program Generally on Track, but Upcoming Schedule Remains Challenging

What GAO Found

The KC-46 program has made good progress over the past year—acquisition costs have remained relatively stable, the critical design review was successfully completed, the program is on track to meet performance parameters, and the contractor started building development aircraft. As shown, total program acquisition costs—which include development, production, and military construction costs—and unit costs have changed less than 1 percent since February 2011.

Initial and Current KC-46 Program Quantities and Acquisition Costs

(then-year dollars in millions)			
	Initial estimate	Current estimate	Change
Total quantities	179	179	0
Total program acquisition costs	\$51,700.2	\$51,376.8	<1%
Average program acquisition unit cost	\$288.8	\$287.0	<1%

Source: GAO presentation of Air Force data.

As of December 2013, Boeing had about \$75 million of its management reserves remaining to address identified, but unresolved development risks. There are indications that the start of initial operational test and evaluation, which is scheduled for May 2016, may slip 6 to 12 months. According to the Director of Operational Test and Evaluation, more time may be needed to train aircrew and maintenance personnel and verify maintenance procedures.

The program released over 90 percent of the KC-46 design drawings at the critical design review, indicating that the design is stable. Overall, development of about 15.8 million lines of software code is progressing mostly according to plan. The next 12 months will be challenging as the program must complete software development, verify that the software works as intended, finalize developmental flight test planning, and begin developmental flight tests. Software problem reports are increasing and Boeing could have difficulty completing all testing if more retests are needed than expected. Developmental flight testing activities are also a concern due to the need for extensive coordination among government agencies, the need for timely access to receiver aircraft (aircraft the KC-46 will refuel while in flight), and the aggressive test pace. The program office is conducting test exercises to mitigate risks and working with Navy and United Kingdom officials to finalize agreements to have access to necessary receiver aircraft.

The program has also made progress in ensuring that the KC-46 is ready for low rate initial production in 2015. Boeing has started manufacturing all four development aircraft on schedule. The program office has identified its critical manufacturing processes and verified that the processes are capable of producing key military subsystems in a production representative environment. In addition, the program has established a reliability growth curve and will begin tracking its progress towards reaching reliability goals once testing begins. Boeing is experiencing some manufacturing delays due to late supplier deliveries on the first aircraft and parts delays for a test article of a critical aerial refueling subsystem, but the program has not missed any major milestones.

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Abbreviations

CDR	critical design review
DOD	Department of Defense
FAA	Federal Aviation Administration

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April 10, 2014

Congressional Committees

The KC-46 tanker modernization program, valued at \$51 billion, is the Air Force's highest acquisition priority. The program recently completed its third year in development to convert an aircraft designed for commercial use into an aerial refueling tanker.¹ Aerial refueling—the transfer of fuel from airborne tankers to combat and airlift forces—is critical to the U.S. military's ability to project power overseas and to effectively operate within a combat theater. It enables military aircraft to fly farther, stay airborne longer, and transport more weapons, equipment, and supplies than unrefueled forces. KC-46 aircraft are expected to replace over forty percent of the KC-135 Stratotanker fleet, currently the mainstay of the U.S. tanker force. This force is now over 50 years old on average and costs increasingly more to maintain and support, with additional concerns that age-related problems could potentially ground the fleet. The Air Force plans to develop, test, and field 18 KC-46 tankers by August 2017, and eventually field a total of 179 aircraft.

The National Defense Authorization Act for Fiscal Year 2012 requires that we annually review and report on the KC-46 program through 2017.² This is our third report reviewing the KC-46 development program. In our first report, we recommended that the Department of Defense (DOD) track lessons learned, since the KC-46 is one of the few major programs to award a fixed price incentive (firm target)³ development contract in recent years.⁴ We also recommended fully implementing sound metrics so planned key performance parameters could be measured appropriately. Subsequently, the program office took steps to do so. In our second

¹ The KC-46 designation refers to the acquisition program, while the actual tanker aircraft being procured is designated the KC-46A. For purposes of this report, we will use the KC-46 designation throughout.

² Pub. L. No. 112-81 § 244 (2011).

³ A fixed price incentive contract provides for adjusting profit and establishing the final contract price by a formula based on the relationship of final negotiated total cost to total target cost. FAR §§ 16.204 and 16.403-1.

⁴ GAO, *KC-46 Tanker Aircraft: Acquisition Plans Have Good Features but Contain Schedule Risk*, [GAO-12-366](#) (Washington, D.C.: Mar. 26, 2012).

report, we recommended that DOD analyze the root causes for the rapid allocation of management reserves (funds set aside to address development risks) and improve the KC-46 master schedule to comply with best practices.⁵ DOD has since reviewed the use of management reserves and is conducting schedule risk assessments. In this third report, we (1) evaluate program progress toward cost, schedule, and performance goals; (2) identify program development challenges, if any, and steps to address these challenges; and (3) assess progress in manufacturing aircraft. The National Defense Authorization Act for Fiscal Year 2012 also requires that we analyze the results of developmental and operational testing and any plans for correcting identified deficiencies. We have not yet assessed testing results and plans to correct identified deficiencies because flight testing has not officially begun.

To conduct work for our current review, we analyzed financial management documents; program budgets; risk assessments; technical performance indicators; flight test and manufacturing plans; and software development plan and metrics. We also analyzed program plans and discussed results with the Air Force's KC-46 program office, other defense offices, and the prime contractor, the Boeing Company (Boeing). We visited Boeing's commercial production line and its facilities for system integration and military modifications.

We conducted this performance audit from May 2013 to April 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. See appendix I for more information on our scope and methodology.

Background

In February 2011, Boeing won the competition to develop the Air Force's next generation aerial refueling tanker aircraft, the KC-46. This program is one of a few weapon system programs to use a fixed price incentive (firm

⁵ GAO, *KC-46 Tanker Aircraft: Program Generally Stable but Improvements in Managing Schedule Needed*, [GAO-13-258](#) (Washington, D.C.: Feb. 27, 2013).

target) contract for development in recent years.⁶ Defense officials stated that a fixed price incentive (firm target) contract was appropriate for the program because KC-46 development is considered to be a relatively low-risk effort to integrate mostly mature military technologies onto an aircraft designed for commercial use. The KC-46 development contract is designed to hold Boeing accountable for cost associated with the development of four test aircraft and includes options to manufacture the remaining production lots.⁷ The contract limits the government's financial liability and provides the contractor incentives to reduce costs in order to earn more profit. Barring any changes to KC-46 requirements by the Air Force, the contract specifies a target price of \$4.4 billion and a ceiling price of \$4.9 billion, at which point Boeing must assume responsibility for all additional costs.⁸ We previously reported that both the program office and Boeing have estimated that development costs would exceed the contract ceiling price. As of March 2014, Boeing and the program office estimated costs would be over the ceiling price by about \$271 million and \$787 million, respectively. The program office estimate is higher because it includes additional costs associated with performance as well as cost and schedule risk.

In all, 13 production lots are expected to be delivered. The contract includes firm fixed price contract options for the first production lot in 2015 and the second production lot in 2016, and options with not-to-exceed firm fixed prices for production lots 3 through 13. The contract also

⁶ In the past, the Department of Defense (DOD) has typically used cost-reimbursement contracts for development wherein the government pays all allowable costs incurred by the contractor to the extent prescribed in the contract. Recent legislation and defense policy now emphasize the use of fixed price development contracts, where warranted, to limit the government's exposure to cost increases.

⁷ For purposes of this report, a production lot refers to a set number of aircraft that must be built and delivered in a given time frame. For example, the first production lot includes seven aircraft that are scheduled to be built and delivered to the Air Force between August 2015 and January 2017.

⁸ The KC-46 development contract with Boeing specifies an incentive ratio for sharing any savings in the event of under runs when the actual contract cost is less than the target cost, or the sharing of additional costs when the actual contract cost is greater than this target cost. The government's share of any cost savings or cost overrun is 60 percent while Boeing's share is 40 percent. This cost sharing arrangement ends when the actual contract cost reaches a level that invokes the contract ceiling price of \$4.9 billion, at which point the contractor is responsible for all additional costs.

requires Boeing to deliver 18 operational aircraft by August 2017.⁹ In addition, all required training must be complete, and the required support equipment and sustainment support in place by August 2017. Contract provisions also specify that Boeing must correct any required deficiencies and bring development and production aircraft to the final configuration at no additional cost to the government. After the first two production lots, the program plans to produce aircraft at a rate of 15 aircraft per year, with the final 6 aircraft procured in fiscal year 2027. Separate competitions may occur for later acquisitions, nominally called the KC-Y and KC-Z, to replace the rest of the KC-135 fleet and the KC-10 fleet (the Air Force's large tanker).

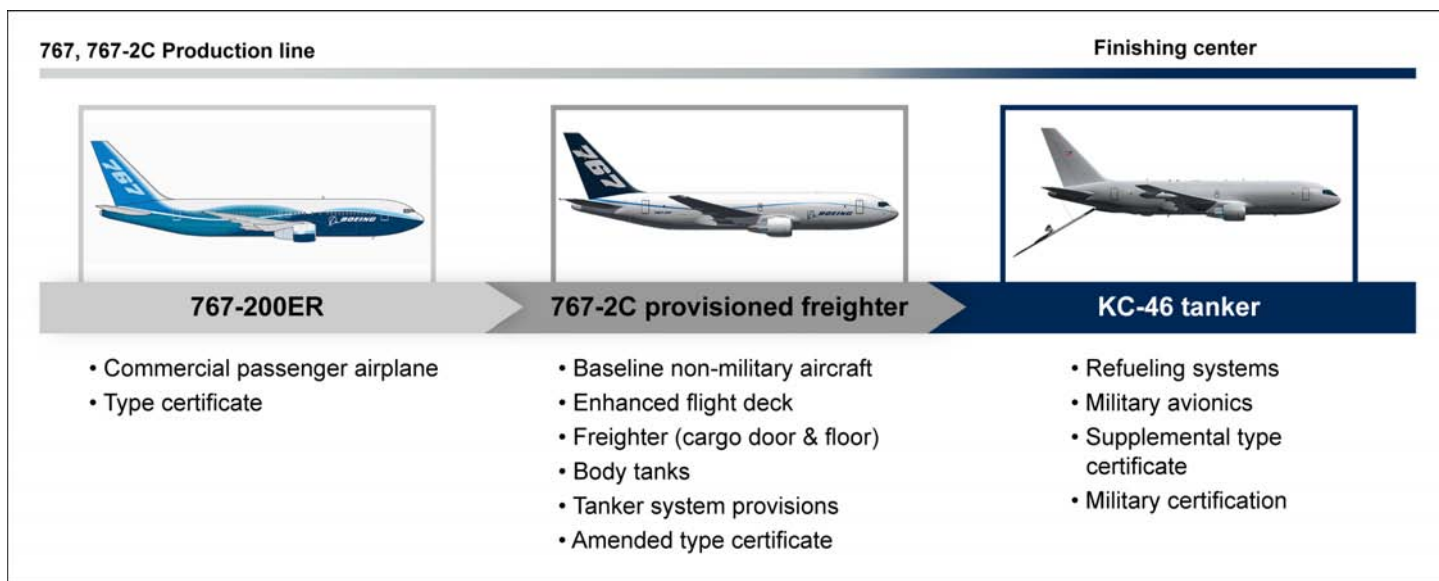
Boeing plans to modify the 767 aircraft in two phases to produce a militarized aerial refueling tanker:

- In the first, Boeing is modifying the 767 with a cargo door and an advanced flight deck display borrowed from its new 787 and calling this modified version the 767-2C. The 767-2C will be built on Boeing's existing production line.
- In the second, the 767-2C will proceed to the finishing center to become a KC-46. It will be militarized by adding air refueling capabilities, an air refueling operator's station that includes panoramic three-dimensional displays, and threat detection and avoidance systems.

The Federal Aviation Administration (FAA) has previously certified Boeing's 767 commercial passenger airplane and will certify the design for both the 767-2C and the KC-46. Boeing established plans for the FAA to accomplish the 767-2C and the KC-46 certifications concurrently rather than consecutively, which is the typical procedure. The Air Force also has to certify the KC-46 and will use the FAA's findings to make the overall airworthiness determination. See Figure 1 for a depiction of the conversion of the 767 aircraft into the KC-46 tanker.

⁹ According to program officials, Boeing plans to use the 4 development aircraft, the 7 aircraft in the first production lot, and 7 of the aircraft in the second production lot in order to meet the contractual requirement to deliver 18 aircraft by August 2017.

Figure 1: Conversion of Boeing 767 into a KC-46 Aerial Refueling Tanker



Source: GAO analysis of Boeing data (data); © Boeing (images).

The new KC-46 tanker is expected to be more capable than the KC-135 it replaces in several respects. Unlike the KC-135, it will allow for two types of refueling to be employed in the same mission—a refueling boom that is integrated with a computer assisted control system, as well as a permanent hose and drogue refueling system.¹⁰ The KC-135 has to land and switch equipment to transition from one mode to another. Also, the KC-46 is expected to be able to refuel in a variety of night-time and covert mission settings and will have countermeasures to protect it against infrared missile threats. The KC-135 is restricted in tactical missions and does not have sufficient defensive systems relative to the KC-46. Designed with more refueling capacity, improved efficiency, and increased cargo and medical evacuation capabilities than its predecessor, the KC-46 is intended to provide aerial refueling to Air Force, Navy, Marine Corps, and allied aircraft. Appendix II compares, in more detail,

¹⁰ Currently, Air Force fixed-wing aircraft refuel with the “flying boom.” The boom is a rigid, telescoping tube that an operator on the tanker aircraft extends and inserts into a receptacle on the aircraft being refueled. Air Force helicopters and all Navy and Marine Corps aircraft refuel using the “hose and drogue.” The “hose and drogue” system involves a long, flexible refueling hose stabilized by a drogue (a small windsock) at the end of the hose. The pilot of the receiving aircraft maneuvers and connects to the hose.

the current capabilities of the KC-135 with the planned capabilities of the new KC-46 tanker.

Program Is Continuing to Meet Cost, Schedule, and Performance Estimates

KC-46 total program acquisition costs (development, production, and military construction costs) have remained relatively stable since program start, changing less than 1 percent since February 2011, and the program is meeting schedule and performance goals. Boeing set aside \$354 million in contract funds to address identified, but unresolved development risks. As of December 2013, Boeing had about \$75 million remaining to address these risks. Based on Boeing's monthly usage, we calculate that the management reserves will be depleted about 3 months before the KC-46's first flight and approximately 3 years before the development contract is completed. The government, however, would bear no financial risk for future work if Boeing uses all of its management reserves as long as the Air Force does not make changes to the KC-46 requirements, schedule, or other relevant terms and conditions of the contract. Our prior work has found that flight testing is likely to uncover problems that will require management reserves to address.

Key Acquisition Cost, Schedule, and Performance Metrics Have Remained Relatively Stable

The KC-46 total acquisition cost estimate has remained relatively stable since February 2011 although there have been some minor fluctuations among the development, procurement, and military construction costs that make up this estimate. The largest change is in the program's development cost estimate, which has decreased by about \$345 million, or about 5 percent. Development cost reductions can be attributed to fiscal year 2013 sequestration cuts, support for DOD's Small Business Innovative Research fund, and cuts to a fund dedicated to tanker replacement.¹¹ According to program officials, these reductions have not affected the program because it had set aside funds to address engineering changes, which have not occurred thus far. Overall, total acquisition and unit costs have decreased less than 1 percent and quantities have remained the same. Table 1 summarizes the initial and

¹¹ The absence of legislation to reduce the federal budget deficit by at least \$1.2 trillion triggered the sequestration process in section 251A of the Balanced Budget and Emergency Deficit Control Act of 1985, as amended. Pursuant to the act, the President ordered sequestration of budgetary resources across non-exempt federal government accounts on March 1, 2013—5 months into fiscal year 2013.

current estimated quantities, costs, and milestone dates for the KC-46 program.

Table 1: Initial and Current KC-46 Program Quantities, Acquisition Costs, and Milestones

	February 2011	October 2013	Change
Expected quantities			
Development quantities	4	4	—
Procurement quantities	175	175	—
Total quantities	179	179	—
Cost estimates (then-year dollars in millions)			
Development	\$7,149.6	\$6,804.5	-4.8%
Procurement	\$40,236.0	\$40,321.4	0.2%
Military construction	\$4,314.6	\$4,250.9	-1.5%
Total program acquisition	\$51,700.2	\$51,376.8	-0.6%
Unit cost estimates (then-year dollars in millions)			
Average program acquisition	\$288.8	\$287.0	-0.6%
Average procurement	\$229.9	\$230.4	0.2%
Key milestones			
Program contract award (Milestone B)	February 2011	February 2011	—
Preliminary design review	April 2012	April 2012	—
Critical design review	July 2013	July 2013	—
Low rate initial production (Milestone C)	August 2015	August 2015	—
Initial operational test and evaluation start	May 2016	May 2016	—
Full rate production decision	June 2017	June 2017	—
Required assets available (18 aircraft operationally ready)	August 2017	August 2017	—

Source: GAO presentation of Air Force data.

The October 2013 development cost estimate of about \$6.8 billion includes several contracts for various activities. For example, the program office awarded Boeing a contract for \$4.9 billion to develop 4 test aircraft and budgeted over \$0.3 billion for the development of aircrew and maintenance training systems.¹² An estimated \$1.6 billion is needed to cover other government costs, such as program office support, test and

¹² The Air Force awarded the Aircrew Training System contract in May 2013 to the FlightSafety Services Corporation for \$78 million. The program office expects the maintenance training system contract to be awarded in fiscal year 2015.

evaluation support, contract performance risk, and other development risks associated with the aircraft and training systems. The procurement cost estimate of \$40.3 billion is to procure 175 production aircraft, initial spares, and other support equipment. The military construction estimate of \$4.2 billion includes the projected costs to build aircraft hangars, maintenance and supply shops, and other facilities to house and support the KC-46 fleet at 10 main operating bases, 1 training base, and the Oklahoma City Air Logistics Complex depot.

Boeing is also meeting the high level schedule milestones. Most recently, it conducted the critical design review (CDR) in July 2013, on schedule. However, there are indications that the start of initial operational test and evaluation, which is scheduled for May 2016, may slip. DOD's Office of the Director, Operational Test and Evaluation, which is responsible for approving operational and live fire test and evaluation within each major defense acquisition program, recently issued its 2013 annual report and continued to recommend that the Air Force plan for a 6- to 12-month delay to the start of initial operational test and evaluation to allow more time to train aircrew and maintenance personnel and verify maintenance procedures. The KC-46 program office agrees that the test schedule is aggressive, but does not believe the delays are certain.

The program office projects that the KC-46 aircraft will meet the requirements of all nine key performance parameters by the end of development.¹³ Satisfying these key performance parameters will ensure that the KC-46 will be able to accomplish its primary mission of providing worldwide, day and night, adverse weather aerial refueling as well as its secondary missions. See appendix III for a list of the KC-46 key performance parameters. The program office has developed a set of metrics to help gauge its progress towards meeting the performance parameters. For example, one metric tracks operational empty weight because in general, every pound of excess weight equates to a corresponding reduction in the amount of fuel the aircraft can carry to accomplish its primary mission. Boeing currently projects that the aircraft will meet the weight target of 204,000 pounds.

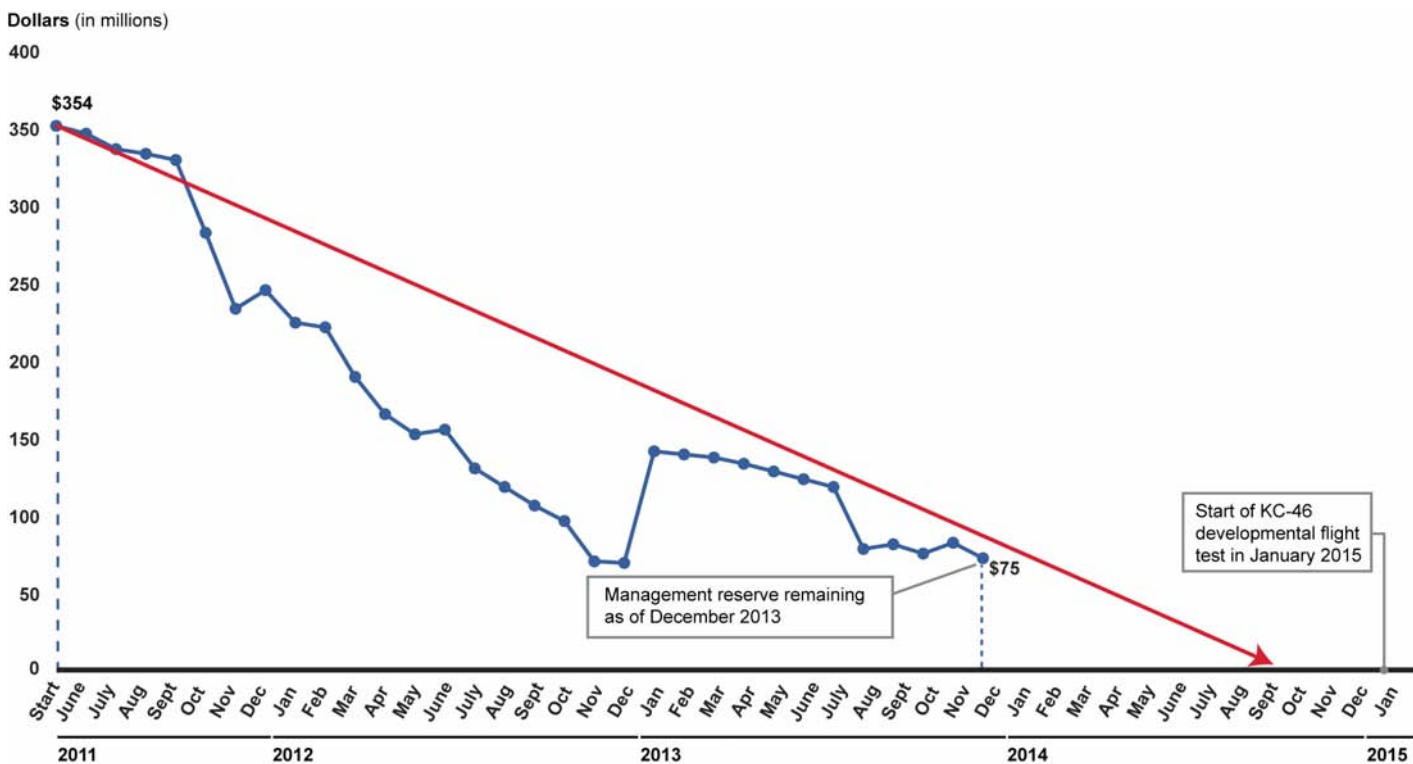
¹³ Key performance parameters are performance attributes of a system considered critical to the development of an effective military capability. They are included verbatim in the acquisition program baseline and may be mandatory or selectively applied, depending on the system.

Funding Set Aside to Alleviate Program Risk Is Almost Depleted

At the outset of development, Boeing set aside \$354 million from contract funds in a management reserve account, about 7 percent of the contract ceiling price, to address identified, yet unresolved, development risks. Last year we reported that Boeing had accomplished approximately 28 percent of the development work and had allocated about 80 percent of the contract's management reserves. We raised concerns about the high rate at which the management reserves were being used because doing so early in a program is often an indicator of future contract performance problems.

Since then, there have been two major actions related to management reserves in 2013. First, in January 2013, Boeing returned \$72 million to the management reserves account because program officials determined that the program would pay for fuel for test flights rather than Boeing, new labor rates were lower than planned, and Boeing calculated costs associated with some types of labor incorrectly. Second, in August 2013, Boeing allocated about \$42 million of its management reserves, with the largest portion, \$24 million, used for a wet fuels laboratory. Boeing initially planned on using corporate funding for the wet fuels laboratory, which was intended for general wet fuels research. However, since the laboratory became more focused on meeting the specific needs of the KC-46 program, Boeing determined it was more appropriate to use management reserves. The other \$18 million was used for a variety of other efforts, including minor design and architectural changes. The following figure illustrates management reserve allocation since program start and projects when reserves will be depleted.

Figure 2: KC-46 Development Contract Management Reserve Allocation and Trend (as of December 2013)



Source: GAO analysis of Boeing prepared contract performance reports.

As of December 2013, about \$75 million in unallocated reserves remain. If the current usage trend continues—a monthly average of over \$9 million—the program office projects management reserves will be depleted in September 2014, about 3 months before the start of KC-46 developmental flight testing and approximately three years before the development contract is completed. According to GAO’s *Cost Estimating and Assessment Guide*, significant use of management reserves early in a program may indicate contract performance problems and decreases the amount of reserves available for future risks, particularly during the test and evaluation phase when demand may be the greatest.¹⁴ Barring any changes to KC-46 requirements, schedule, or other relevant terms and conditions of the contract by the Air Force, Boeing would be solely

¹⁴ GAO, *GAO Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Capital Program Costs*, [GAO-09-3SP](#) (Washington, D.C.: March 2009).

responsible for the cost of future changes if it uses all of its management reserves, so the government bears no financial risk.

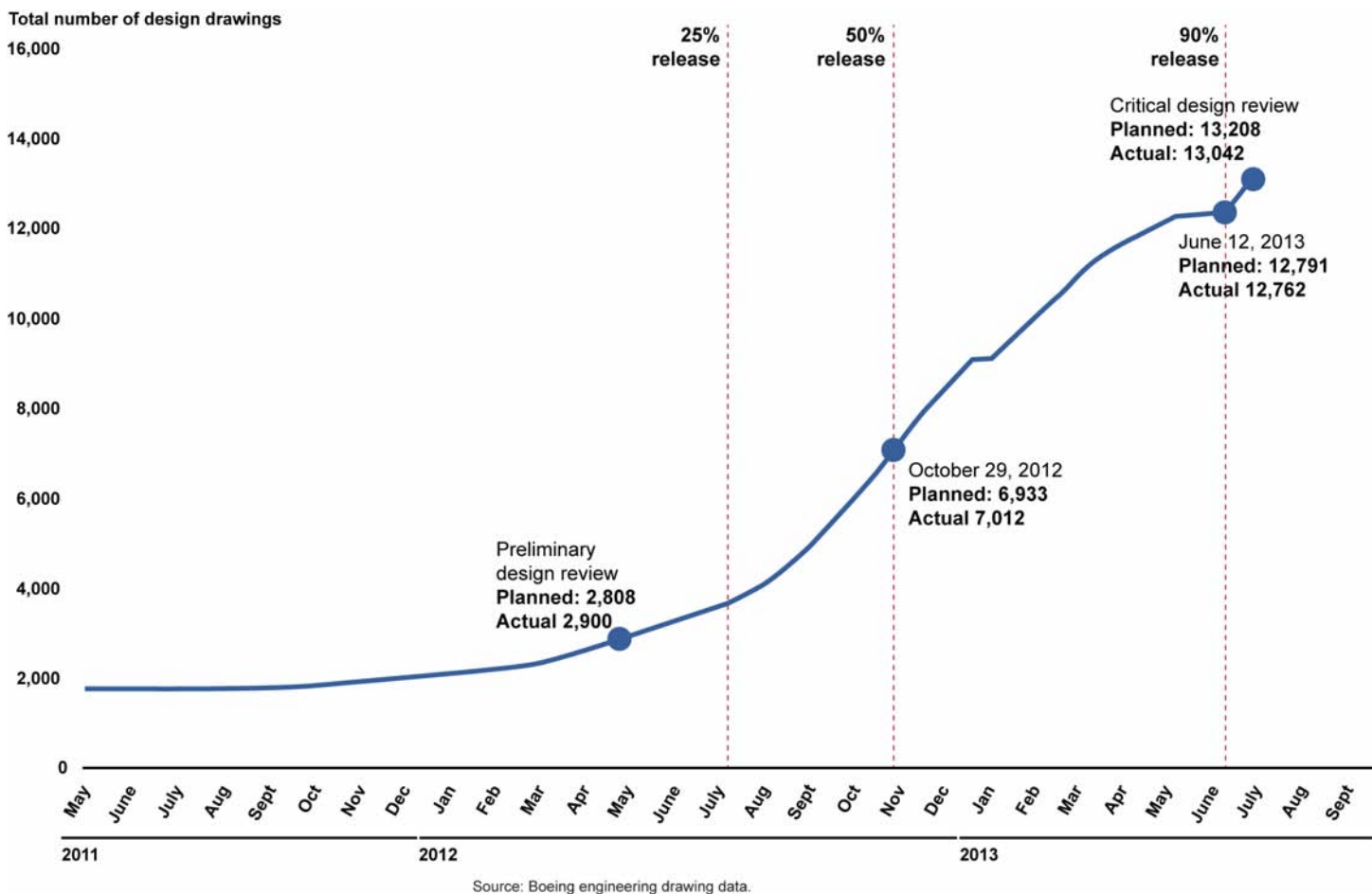
Program Stabilized the KC-46 Design and Is Now Focused on Software Development and Testing Challenges

The program office and Boeing held the program's CDR in July 2013 and released over 90 percent of the total engineering design drawings, a key indicator that the design is stable. The program is now focused on completing software development and integration, as well as test plans in preparation for developmental flight testing. Software development plans changed over the course of the past year in large part because the program solidified requirements at CDR and Boeing brought two of the program's software intensive system components in-house and found ways to use some of its existing software. Overall, software development is progressing largely according to plan; however, software verification testing has not yet started and software problem reports are increasing. The flight test program is also a concern because it depends on coordination among several separate government entities, requires timely access to receiver aircraft (the aircraft the KC-46 will refuel while in flight), and requires a more aggressive pace than on past programs. The program office is conducting a series of rehearsal test exercises and is working with Air Force officials to finalize agreements related to receiver aircraft availability to mitigate these risks.

Program Successfully Completed Its Critical Design Review

The program office held its CDR in July 2013, with Boeing releasing over 90 percent of the total engineering design drawings. The 90 percent drawing release met a contractual requirement and is consistent with acquisition best practices that use this metric as an indicator that the design is stable. According to program officials, as of December 2013, Boeing had released 98.6 percent of the expected engineering design drawings and the remaining drawings relate almost exclusively to aircraft interiors and are not considered to be complex. Figure 3 shows the number of design drawings completed since Boeing began tracking it in May 2011.

Figure 3: KC-46 Engineering Design Drawing Completion Status through the Critical Design Review



Prior to CDR, the program office and Boeing took a number of steps to ensure the program had a stable design. This included holding a series of sub-system CDRs, replacing two system components that were not sufficiently mature, and addressing previously identified risks, such as aircraft weight. Currently, Boeing is working to alleviate lingering instability in key physical components related to aerial refueling—the centerline drogue system and wing aerial refueling pod. Boeing still considers the instability of these components to be a moderate program risk, and its strategy is to conduct modeling and simulation studies and perform ground tests to help mitigate this risk.

Software Development Is Progressing

As of January 2014, Boeing estimates that 15.8 million lines of code will be needed for the KC-46. Boeing plans to rely primarily on reused software from its commercial aircraft for the 767-2C and more heavily on modified or new software for the military subsystems on the KC-46. As shown in table 2, the most recent plan is for Boeing to reuse existing software for 83 percent of its software needs, which has helped reduce risks associated with software development.

Table 2: Changes to the Planned Composition of KC-46 Software

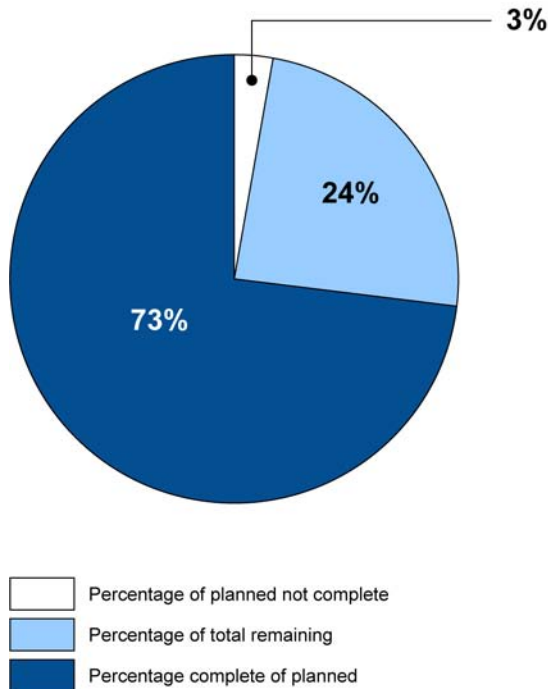
Software type	Program start 2011	Critical design review 2013
Reused	76%	83%
Modified	18%	12%
New	6%	5%

Source: GAO presentation of KC-46 Air Force Program Office and Boeing data.

According to program officials, the changes in reused, modified, and new software between 2011 and 2013 are largely the result of the program solidifying requirements for CDR and Boeing's effort to reduce the risk associated with the development of two software-intensive system components related to situational awareness. According to these officials, there were limitations with the original software developer's software and Boeing ultimately decided to bring the development effort in-house, leveraging existing software code to mitigate risk.

Overall, we found that software development is currently progressing mostly according to Boeing's plan. As shown in figure 4, as of January 2014, Boeing reported that 73 percent of software had been delivered compared to its plan for having 76 percent at this time (96 percent of the planned activities).

Figure 4: Software Delivery Completed (as of January 2014)



Source: GAO presentation of Boeing data.

A large portion of the software that has been delivered to this point is reused software that is needed for the initial build of the 767-2C aircraft. A small amount of development work related to the aerial refueling software, about 3 percent, is behind schedule. The remaining software, related to key military subsystems for remote vision and situational awareness, among other capabilities, is expected to be delivered to Boeing through the beginning of June 2014.

Software Test Schedule Will Be Challenging

While the program's progress for software development is encouraging, program officials are expecting software verification testing, which has not yet begun, to be challenging. Notably, Boeing must verify the software code to determine if it works as intended. Approximately 735,000 lines of the code are new and relate in large part to key military unique systems. Moreover, Boeing's software integration lab that simulates the KC-46 cockpit will be at near capacity between February and June 2014. Boeing could have difficulty completing all testing if more retests are needed than expected.

In addition to capacity concerns, we found that software problem reports are increasing. There were over 600 software problem reports as of January 2014 that needed to be addressed, which will add pressure to an integration lab already operating at near capacity. Thirty-five percent of the problem reports were considered urgent or high priority problems that need to be fixed as quickly as possible. Program officials stated that avionics flight management computer software has been a major contributor to the problem reports to date and that Boeing is working closely with this supplier to ensure problems are addressed. This particular supplier has recently increased the number of staff working on this software effort from 3 to 24 people to address the backlog of problem reports.

Pace of Flight Test Schedule Poses Future Risk

The program's flight test schedule continues to be a concern due to the need for extensive coordination among government entities, the need for timely access to receiver aircraft, and its aggressive pace. The following is a summary of the various testing concerns and the steps, if any, the program office and Boeing are taking to address them.

- *Coordinating on concurrent test activities:* Government agencies and Boeing have agreed to a "test once" approach, whereby many of the test activities for FAA certification, developmental testing, aerial refueling, and operational testing will be combined to achieve greater efficiency.¹⁵ Currently, Boeing, the program office, the Air Force, Navy, FAA, and officials from the Office of the Secretary of Defense organizations for developmental and operational testing are finalizing detailed test plans, which are needed to guide flight test activities that are scheduled to begin in June 2014 for the 767-2C and in January 2015 for the KC-46. The program office is conducting a series of rehearsal test exercises before any flight tests take place to ensure that all parties understand their roles and responsibilities during testing. Program officials report that three of four such exercises have been completed, with the next scheduled for September 2014. Officials said this exercise will focus on preparing for the KC-46's first flight.

¹⁵ The program office reported that the expected number of tests as of February 2014 includes, but is not limited to, 50 FAA certification-related test plans and 137 combined FAA and specification verification test plans. Additional non-FAA military certification and specification verification test plans are not yet available.

-
- *Ensuring receiver aircraft availability:* To meet the test schedule, receiver aircraft, such as the F-22 A and the F/A-18 C, are needed at certain locations and times to participate in the program's test activities. The program office has finalized one memorandum of agreement with Air Force officials for access to 14 receiver aircraft and stated that it is currently in the process of developing two additional agreements with the Navy for two additional types of aircraft and the United Kingdom for their respective aircraft. If the receiver aircraft are not available when needed, the Air Force risks affecting Boeing's test schedule.
 - *Maintaining flight test pace:* The program office and Boeing report that maintaining the program's flight test pace is among the program's greatest risks. Program officials explained that this risk captures both the 65 hour per month commercial test pace for the 767-2C aircraft and the 50 hour per month military test pace for the KC-46 aircraft. To adhere to the aggressive test schedule, Boeing officials stated that they plan to fly development aircraft 5 to 6 days per week with roughly 5 to 6 hours per mission (which DOD test organizations have shown is more aggressive for the military flight testing than other programs have demonstrated historically).¹⁶ Boeing officials believe they can achieve the test pace required because of Boeing's testing experience with other commercial aircraft and the KC-10 tanker program. In addition, Boeing has local maintenance and engineering support available to support the test program as well as control over flight test priorities for the commercial testing since the development aircraft are being tested at Boeing facilities.

Manufacturing Has Begun with Some Delays

The program has made progress in readying the KC-46 for low rate initial production in 2015. Boeing has started manufacturing all four development aircraft on schedule, but has experienced some delays with the first aircraft. The program office and Boeing have also taken several steps to capture the necessary manufacturing knowledge to make informed decisions as the program transitions from design into production. This includes identifying and assessing critical manufacturing processes to determine if they are capable of producing key military subsystems in a production representative environment. The program

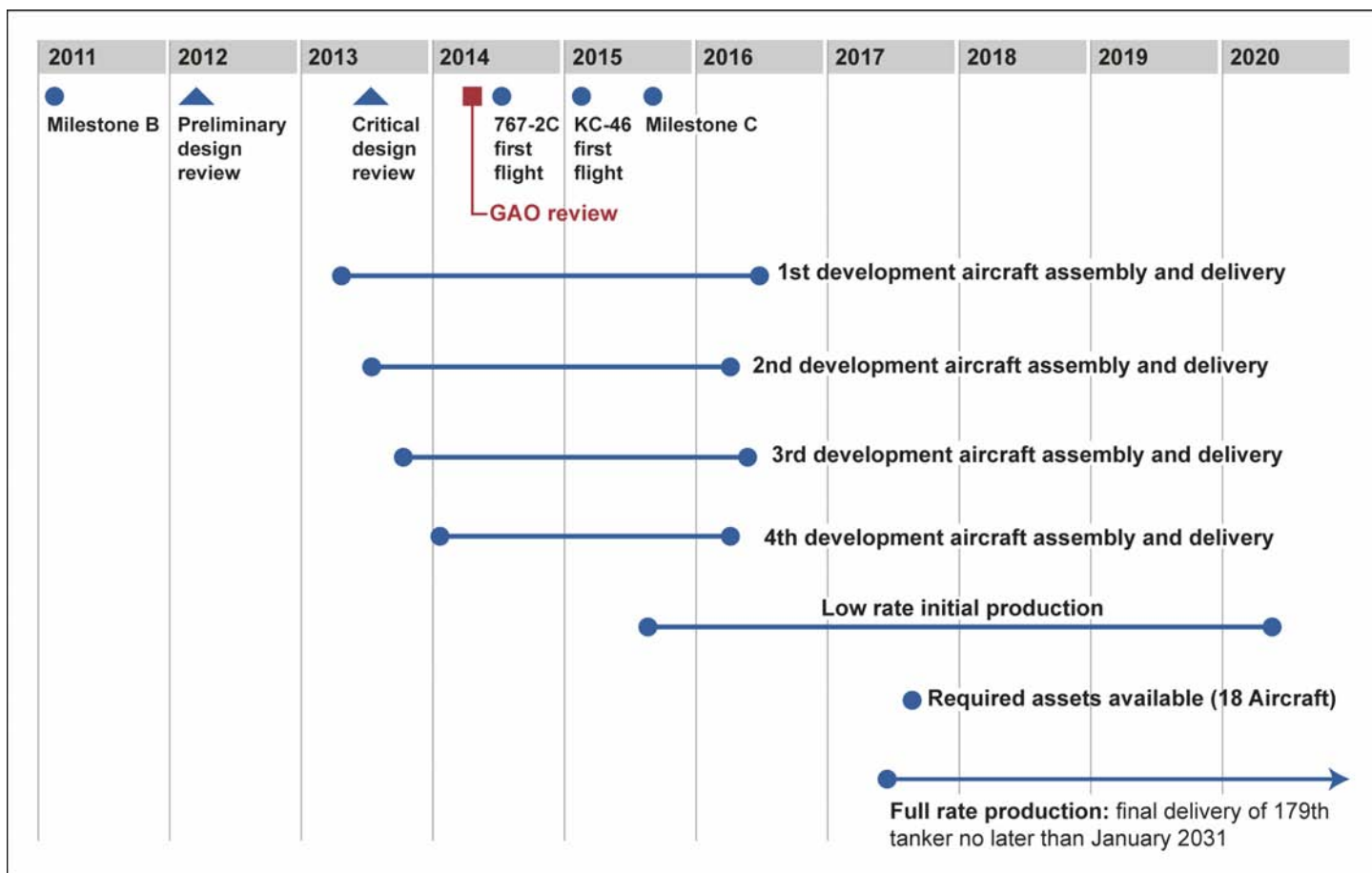
¹⁶ The first and third development aircraft have been assigned to participate in commercial flight tests and the second and fourth development aircraft will participate in the military flight tests.

also established a reliability growth curve and Boeing will begin tracking its progress towards reaching reliability goals once testing begins. Boeing is making progress manufacturing most of the military unique subsystems, but a test article for a critical aerial refueling subsystem has been delayed by almost a year due to parts issues.

Development Aircraft Manufacturing Has Started

Boeing has started manufacturing all four development aircraft on schedule, but has experienced some delays with the first aircraft. The Air Force plans to eventually field a total of 179 aircraft no later than January 2031. Figure 5 displays the time line for the manufacture of the development, low rate production, and full rate production aircraft.

Figure 5: KC-46 Tanker Production Time Line



Source: GAO presentation of Air Force data.

Note: The low rate initial production end date in the figure above assumes that Milestone C will occur in August 2015. Based on that assumption, the contract requires that the last low rate production aircraft be delivered no later than March 2020. The full rate production end date assumes that the decision to proceed into full rate production will occur in June 2017. Based on that assumption, the contract stipulates that the last full rate production aircraft be delivered no later than January 2031.

Boeing began producing the first development aircraft (a 767-2C) in June 2013, and Boeing officials said the aircraft was 76 percent complete as of mid January 2014. The aircraft was scheduled to be powered on for the first time in early December 2013, but program officials told us that activity has slipped until the end of April 2014. Boeing officials attributed the schedule slip to late supplier deliveries. Completion of major assembly operations has also slipped from mid January until mid March. Program officials told us that Boeing has been able to resequence tasks

thus far to avoid affecting the critical path,¹⁷ such as adding the body fuel tanks to the first 767-2C earlier and in a different facility than originally planned. Program officials are assessing whether these delays will affect the timing of the first flight of the 767-2C, scheduled for June 2014.

Boeing and program officials said that manufacturing of the second development aircraft was going better than on the first aircraft, reporting that the aircraft was 65 percent complete as of mid January 2014. Officials added that there had been a 75 percent reduction in overall parts shortages. The third and fourth aircraft just began production in late October 2013 and mid January 2014, respectively. From the first to the fourth development aircraft, Boeing is anticipating improvement in its ability to manufacture the aircraft. For example, the first aircraft is scheduled to take about 11 and a half months from the start of major assembly until first flight while the fourth aircraft is only scheduled to take about 7 months. Once complete, the four development aircraft will then enter the finishing center at various points between June 2014 and September 2015 to be converted to a KC-46 tanker.

Program Is Capturing Manufacturing Knowledge

The program office and Boeing have taken several initial steps to help ensure that the KC-46 will be ready for low rate production in August 2015 and that the aircraft will be reliable. In our prior work, we identified the activities required to capture manufacturing knowledge.¹⁸ These activities include (1) identifying key system characteristics and critical manufacturing processes; (2) establishing a reliability growth plan and goals; (3) conducting failure modes and effects analysis; (4) conducting reliability growth testing; and (5) determining whether processes are in control and capable. Table 3 provides a description of these activities and progress the program has made for each.

¹⁷ The critical path defines the program's earliest completion date or minimum duration it will take to complete all activities.

¹⁸ GAO, *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, [GAO-02-701](#) (Washington, D.C.: July 15, 2002).

Table 3: Activities to Capture Manufacturing Knowledge

Activity description	Program progress
Identify key system characteristics and critical manufacturing processes: A product's key characteristics and critical manufacturing processes should be identified early. Because there can be thousands of manufacturing processes required to build a product, companies focus on the critical processes—those that build parts that influence the product's key characteristics such as performance, service life, or manufacturability.	Completed
Set reliability growth plan and goals: A product's reliability is its ability to perform over an expected period of time without failure, degradation, or need of repair. A growth plan is developed to mature the product's reliability over time through reliability growth testing so that it has been demonstrated by the time production begins.	Completed
Conduct failure modes and effects analysis: Bottom-up analysis is done to identify potential failures for product reliability. It begins at the lowest level of the product design and continues to each higher tier of the product until the entire product has been analyzed. It allows early design changes to correct potential problems before fabricating hardware.	Initiated
Conduct reliability growth testing: Reliability growth is the result of an iterative design, build, test, analyze, and fix process for a product's design with the aim of improving the product's reliability over time. Design flaws are uncovered and the design of the product is matured.	Not Started
Determine processes in control and capable: Statistical process control is used to determine if processes are consistently producing parts. Once control is established, an assessment is made to measure the process's ability to build a part within specification limits as well as how close the part is to that specification. A process is considered capable when it has a defect rate of less than 1 out of every 15,152 parts produced.	Not Started

Source: GAO.

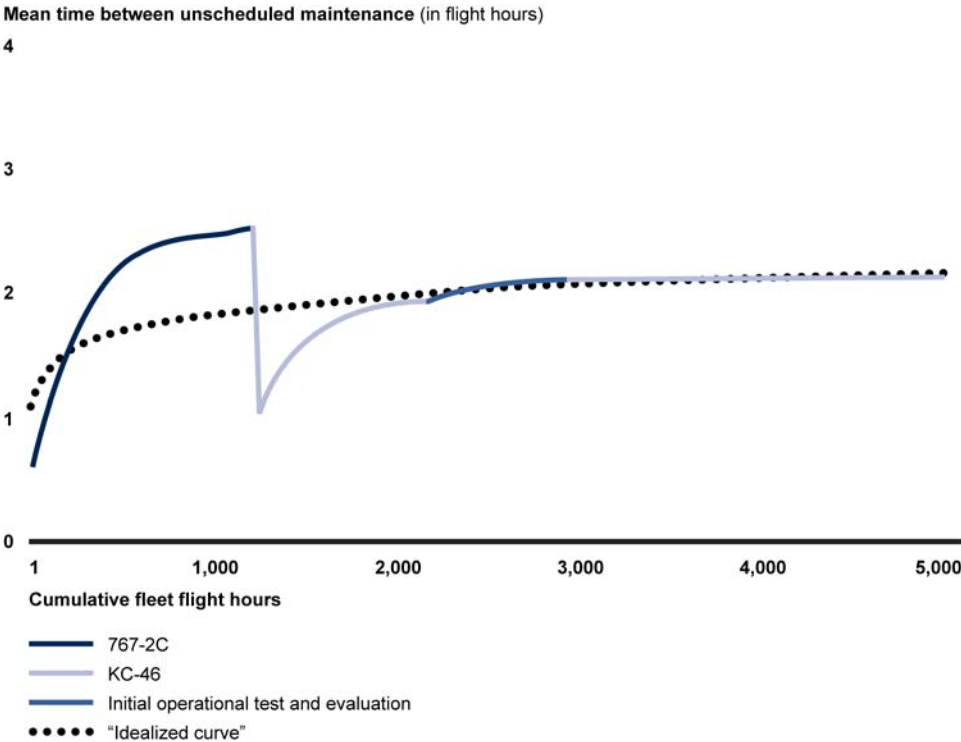
Since the 767-2C will be manufactured on Boeing's existing 767 production line, the program office and Boeing have focused their attention on identifying the key system characteristics and critical manufacturing processes for the military unique subsystems. Prior to CDR, the program office and Boeing completed assessments of 12 critical manufacturing processes, such as the assembly of aerial refueling components. These assessments indicated that key military subsystems could be manufactured in a production representative environment. The program office and Boeing plan on conducting another assessment prior to August 2015 to determine if the program is ready to begin low rate initial production.

The program office has established a reliability growth curve and goal. To assess reliability growth, the program is tracking the mean time between unscheduled maintenance events due to equipment failure, which is defined as the total flight hours divided by the total number of incidents requiring unscheduled maintenance.¹⁹ These failures are caused by a

¹⁹ Mean time between unscheduled maintenance is not a contractual metric.

manufacturing or design defect and require the use of Air Force resources, such as spare parts or manpower, in order to fix them. The program has set a reliability goal of 2.83 flight hours between unscheduled maintenance events, but does not expect that goal to be achieved until the program has logged 50,000 flight hours. Figure 6 below depicts how the program office expects the aircraft's reliability to improve over the program's initial 5,000 flight hours.

Figure 6: Initial Reliability Growth Curve for 767-2C and KC-46 Aircraft



Source: GAO presentation of Air Force data.

The program expects to be above the idealized reliability growth curve at the start of testing because initial testing will be on a 767-2C, a derivative of a commercial aircraft that has been flying since the 1980s. Reliability is projected to fall below expectations once the military sub-systems are added to the aircraft. The program then expects the reliability to steadily improve to the point where the aircraft could fly about 2 hours between unscheduled maintenance events at the start of initial operational test and evaluation. As shown in figure 6 above, the program will be on the idealized reliability growth curve at that point.

Boeing has also initiated a failure modes and effects analysis that covers 41 subsystems. Boeing and the program office rely on this analysis to determine which subsystems on the aircraft are likely to fail, when and why they fail, and whether those subsystems' failures might threaten the aircraft's safety. Boeing is also using this information to develop a tool to detect and log equipment failures. The program office plans to share the analysis with aircraft maintenance staff.

The program has not yet begun two critical manufacturing and reliability assessment activities. First, the program is not currently tracking reliability growth because the 767-2C first flight is not scheduled to take place until June 2014 and no flight hours have been accrued yet. Second, the program has not determined whether manufacturing processes are in control and capable of producing parts consistently with few defects. The program plans to review and verify that process controls are in place to ensure the quality of the manufacturing process as part of its next assessment of critical manufacturing processes prior to the low rate production decision in August 2015. Program officials said their review would be focused on whether these process controls are in place rather than analyzing the data to determine if the processes are actually in control.

Status of Key Military Subsystems

Boeing is making progress manufacturing most of the military unique subsystems, such as the aerial refueling operator station, but the test refueling boom's schedule has slipped by almost a year due to parts delays. Boeing's original design included parts that proved challenging to fit within the boom's space constraints, and other parts were redesigned to improve the boom's safety. Boom parts suppliers, however, have experienced delays in delivering the redesigned parts to Boeing, which has prompted Boeing to send staff to help one of the suppliers minimize further schedule slips. Boeing officials told us they decided to build a test boom as a risk reduction effort and plan to apply lessons learned from producing the test boom to future boom production. However, program officials currently estimate that boom parts delays have also led to an approximately 1-month schedule slip in the first development aircraft's boom. Boeing is facing some schedule pressure on this boom because it is now scheduled to be completed only a few days before the start of ground vibration testing. Boeing officials said they needed the boom for this testing and would like to complete ground vibration testing before the 767-2C's first flight. The second development aircraft's boom is scheduled to be built in only 5 months. Based on its current schedule,

Boeing needs to have this boom completed by June 2014 in order to meet the KC-46's first flight, scheduled for January 2015.

Conclusions

The KC-46 program has made good progress to date—acquisition costs have remained relatively stable, high-level schedule and performance goals have been met, the critical design review was successfully completed, and the contractor is building development aircraft. The next 12 months will be challenging as the program must accomplish a significant amount of work and the margin for error is small. For example, the program is scheduled to complete software integration and the first test flights of the 767-2C and KC-46. The remaining software development and integration work is mostly focused on military software and systems and is expected to be more difficult relative to the prior work completed. The program's test activities continue to be a concern due to its aggressive test schedule. Detailed test plans must be completed and the program must maintain an unusually high test pace to meet this schedule. Perhaps more importantly, agencies will have to coordinate to concurrently complete multiple air worthiness certifications. While efficient, this approach presents significant risk to the program. The program office must also finalize agreements now in progress to ensure that receiver aircraft are available when and where they are needed to support flight tests. Any discoveries made in testing that require design changes may negatively affect program schedule and delivery to the warfighter. Parts delays on the first development aircraft and a critical aerial refueling subsystem are also causing increased schedule pressure.

With these risks in its near future, the KC-46 program will continue to bear watching. While all of the risks currently appear to be recognized, any slips in software testing, flight testing, and manufacturing as the program moves forward could cause delays in the program.

Recommendation for Executive Action

Due to existing schedule risks and the fact that the program is entering a challenging phase of testing, we recommend that the Secretary of Defense direct the Air Force to study the likelihood and potential effect of delays on total development costs, and develop mitigation plans, as needed, related to potential delays.

Agency Comments

DOD provided us with written comments on a draft of this report, which are reprinted in appendix V. DOD concurred with our recommendation. The KC-46 program office conducts an annual analysis of cost and schedule risks to quantify the potential effect of delays on program costs and officials told us they will consider the risks we identified in that analysis. We also incorporated technical comments from DOD as appropriate.

We are sending copies of this report to the Secretary of Defense; the Secretary of the Air Force; and the Director of the Office of Management and Budget. The report is also available at no charge on the GAO website at <http://www.gao.gov>.

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

A handwritten signature in black ink, appearing to read 'Michael J. Sullivan', with a stylized, flowing script.

Michael J. Sullivan
Director
Acquisition and Sourcing Management

List of Committees

The Honorable Carl Levin
Chairman
The Honorable James Inhofe
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Richard Durbin
Chairman
The Honorable Thad Cochran
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Howard P. McKeon
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Rodney Frelinghuysen
Chairman
The Honorable Peter Visclosky
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Objectives, Scope, and Methodology

This report examines the Air Force's continued development of the KC-46 tanker program. Specifically, we examined (1) progress toward cost, schedule, and performance goals; (2) development challenges, if any, and steps to address them; and (3) progress in manufacturing the aircraft.

To assess progress toward cost, schedule and performance goals in the calendar year of this review (2013), we reviewed briefings by program and contractor officials, financial management documents, program budgets, defense acquisition executive summary reports, selected acquisition reports, monthly activity reports, technical performance indicators, risk assessments, and other documentation. To evaluate cost information, we analyzed earned value management data and the contractor's use of management reserves. To assess development schedule progress, we compared program milestones established at program start to current estimates and reviewed Defense Contract Management Agency monthly assessments of KC-46 schedule health and program office schedule analyses. We also interviewed program officials to determine the status of Department of Defense (DOD) efforts to implement our prior recommendations aimed at improving the program's integrated master schedule. To measure progress toward performance goals, we reviewed current estimates of key performance parameters, key system attributes, and technical performance metrics and compared them to threshold and objective requirements. We discussed results of the initial KC-46 operational assessment with officials from the Air Force Operational Test and Evaluation Center and the Director of Operational Test and Evaluation. We also interviewed relevant officials from the KC-46 program office, Boeing, and the Department of Defense.

To assess development challenges and steps to address them, we examined program documentation, such as critical design review briefings, risk assessments and briefings, software metrics reports, integrated test team meeting minutes, and updates to key documents such as the technology maturation, software development, and integrated test plans. We also analyzed pertinent DOD documents including the Defense Contract Management Agency's monthly program assessment reports, the first operational assessment by the Air Force Operational Test and Evaluation Center, and annual reports issued by the Deputy Assistant Secretary of Defense for Developmental Test and Evaluation and the Director of Operational Test and Evaluation. When possible, we attended integrated test team and program management meetings to obtain additional insight on any challenges or mitigation efforts being discussed by Boeing and program officials. In addition, we examined the

program's progress in completing design drawings and maturing critical technologies at the critical design review. Furthermore, we interviewed officials from Boeing, the program office, the Office of the Secretary of Defense, and the Department of the Navy to assess development challenges and the suitability of steps taken to address them.

To assess progress in manufacturing aircraft, we analyzed program office and Boeing documents, such as the manufacturing program plan; quarterly manufacturing and quality briefings; and program schedules. We used these documents to compare Boeing's initial schedule for completing aircraft and boom manufacturing to its actual performance and to identify challenges, if any. We also evaluated whether the program captured manufacturing knowledge recommended in prior GAO best practices work. This included reviewing manufacturing readiness assessments and comparing the results and future plans to DOD guidance and manufacturing best practices identified in prior GAO work. Lastly, we interviewed Boeing and program officials to discuss manufacturing progress and challenges and conducted a site visit of Boeing's 767 production line and its temporary and permanent boom production facility and finishing center.

We conducted this performance audit from May 2013 to April 2014 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Comparison of Current KC-135 Versus Planned KC-46 Performance Capabilities

Capability area	KC-135 	KC-46 
Primary function	Aerial refueling and airlift with 200,000 lbs total fuel for refueling	Aerial refueling and airlift with 212,000 lbs total fuel for refueling
Boom refueling	Hydraulic system with 1,176 gallons per minute refueling rate	Computer assisted with 1,200 gallons per minute refueling rate
Probe and drogue refueling	Permanent system does not exist – must be temporarily added	Permanent centerline probe and drogue system
Boom and probe & drogue refueling on same mission	Not capable of both on same mission	Capable of using both refueling types on the same mission
Refueling of two aircraft at the same time	Limited to 20 tankers with the capability to attach wing pods and conduct multipoint refueling of two aircraft	All tankers have the capability to attach wing pods and conduct multipoint refueling, but only 46 sets of wing pods will be procured
Cargo/passenger/medical patient	6 cargo pallets, 53 passengers, 44 medical patients	18 cargo pallets, 114 passengers, 54 medical patients
Defensive systems	Does not possess sufficient systems	Protection from nuclear, infrared (heat seeking missiles), and biochemical threats
Night-time refueling	Restricted in tactical missions	Able to refuel in tactical missions

Source: GAO presentation of Air Force information (data); © Boeing Company (images)

Appendix III: Description of Key Performance Parameters

Key performance parameter	Description
Tanker Air Refueling Capability	Aircraft shall be capable of accomplishing air refueling of all Department of Defense current and programmed (budgeted) receiver aircraft. The aircraft shall be capable of conducting both boom and drogue air refueling on the same mission.
Fuel Offload versus Radius	Aircraft shall be capable of carrying certain amounts of fuel (to use in air refueling) certain distances.
Operate in Civil and Military Airspace	Aircraft shall be capable of worldwide flight operations in all civil and military airspace.
Airlift Capability	Aircraft shall be capable of transporting certain amounts of both equipment and personnel.
Receiver Air Refueling Capability	Aircraft shall be capable of receiving air refueling from any compatible tanker aircraft.
Force Protection	Aircraft shall be able to operate in chemical and biological environments.
Net-Ready	Aircraft must be able to have effective information exchanges with many other Department of Defense systems to fully support execution of all necessary missions and activities.
Survivability	Aircraft shall be capable of operating in hostile threat environments.
Simultaneous Multi-Point Refueling	Aircraft shall be capable of conducting drogue refueling on multiple aircraft on the same mission.

Source: GAO presentation of Air Force data.

Appendix IV: KC-46 Critical Technology Elements

Critical technology	Description	Testing to date
3-Dimensional Display	The display screens at boom operator stations inside the aircraft provide the visual cues needed for the operator to monitor the aircraft being refueled before and after contact with the refueling boom or drogue. The images of the aircraft on the screens are captured by a pair of cameras outside the aircraft that are meant to replicate the binocular aspect of human vision by supplying an image from two separate points of view, replicating how humans see two points of view, one for each eye. The resulting image separation provides the boom operator with greater fidelity and a more realistic impression of depth, or a 3rd dimension.	Similar technology has been used on two foreign-operated refueling aircraft and a representative model in tests with other Boeing tankers.
Tactical Situational Awareness System Reactive Threat Avoidance—Route Generation Engine	The route generation engine is a component of the reactive threat avoidance sub-system. This sub-system monitors for ground and surface threats based on the aircraft's location and the active flight route. It identifies threats that impact the current route, provides a safer alternative route, and alerts the pilot that a new route is available for review and acceptance.	A recent version of the route generation engine was flown and demonstrated on a Navy aircraft, but improvements have been made that have not been flight tested.

Source: GAO presentation of Air Force information.

Appendix V: Comments from the Department of Defense



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Michael J. Sullivan
Director, Acquisition and Sourcing Management
United States Government Accountability Office
441 G St NW
Washington DC 20548

Dear Mr. Sullivan

This is the Department of Defense (DoD) response to the GAO Draft Report GAO-14-190, "KC-46 TANKER AIRCRAFT: Program Generally on Track, but Upcoming Schedule Remains Challenging," February 27, 2014 (GAO Code 121147).

The DoD concurs with the recommendation to determine the likelihood and potential impacts of delays on total development costs, and develop mitigation plans, as needed, related to potential delays. The Program Office accomplishes a comprehensive analysis of cost and schedule risk impacts during its annual Integrated Risk Assessment (IRA) and Schedule Risk Assessment (SRA). These analyses are used to quantify the potential delays and cost risk in the annual Program Office estimate.

Again, thank you for the opportunity to review this report. If you have any questions, please contact Mr. Michael Kalna, michael.s.kalna.civ@mail.mil, (571) 256-0494, the Air Force's Primary Action Officer, or my point of contact Maj Mark Pride, mark.pride@us.af.mil, (937) 656-9336.

Sincerely,

A handwritten signature in black ink, appearing to read "Chris Coombs", is written over a horizontal line.

CHRISTOPHER M. COOMBS, Col, USAF
KC-46 System Program Manager

**GAO DRAFT REPORT DATED FEBRUARY 27, 2014
GAO-14-190 (GAO CODE 121147)**

**"K-46 TANKER AIRCRAFT: PROGRAM GENERALLY ON TRACK, BUT
UPCOMING SCHEDULE REMAINS CHALLENGING."**

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

RECOMMENDATION 1: The GAO recommends that the Air Force determine the likelihood and potential impact of delays on total development cost, and develop mitigation plans, as needed, related to potential delays.

DoD RESPONSE: The DoD concurs with the recommendation to determine the likelihood and potential impacts of delays on total development costs, and develop mitigation plans, as needed, related to potential delays. The Program Office accomplishes a comprehensive analysis of cost and schedule risk impacts during its annual Integrated Risk Assessment (IRA) and Schedule Risk Assessment (SRA). These analyses are used to quantify the potential delays and cost risk in the annual Program Office estimate.

Appendix VI: GAO Contact and Acknowledgments

GAO Contact

Michael Sullivan (202) 512-4841 or sullivanm@gao.gov

Acknowledgments

In addition to the contact name above, the following staff members made key contributions to this report: Cheryl Andrew, Assistant Director; Jeff Hartnett; Katheryn Hubbell; John Krump; LeAnna Parkey; and Robert Swierczek.

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