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Report to the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives

March 2021

HEAVY LIFT HELICOPTER PROGRAM

Navy Should Address Cost and Schedule Risks

Accessible Version

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GAO-21-208

GAO Highlights

Highlights of GAO-21-208, a report to the Subcommittee on Tactical Air and Land Forces, Committee on Armed Services, House of Representatives

March 2021

HEAVY LIFT HELICOPTER PROGRAM

Navy Should Address Cost and Schedule Risks

Why GAO Did This Study

The Marine Corps is replacing its aging CH-53E helicopters with the CH-53K heavy-lift helicopter. Designed as an evolution of the CH-53E, the CH-53K is intended to transport armored vehicles, equipment, and personnel from ships to deep inland locations. The CH-53K program office is overseen by the Department of the Navy. As we have previously reported, the program has experienced delayed milestones and cost increases from almost its inception in 2005, in part, due to technical issues.

GAO was asked to review the CH-53K program. This report examines the program's (1) progress toward completing testing and demonstrating system experience, (2) schedule and cost performance to date, and (3) potential future challenges.

GAO analyzed cost, schedule, performance, test, manufacturing, and planning documents; and interviewed officials from the CH-53K program office, other defense offices—such as the Defense Contract Management Agency—the testing community, and the prime contractor, Sikorsky.

What GAO Recommends

GAO recommends that the Navy take steps to ensure the CH-53K schedule is credible and well-constructed, and that the Navy should not exceed the current annual procurement of six helicopters per year until the completion of initial operational test and evaluation. The Department of Defense did not concur with these recommendations. GAO continues to believe that the recommendations are valid, as discussed in this report.

View GAO-21-208. For more information, contact Jon Ludwigson at (202) 512-4841 or ludwigsonj@gao.gov.

What GAO Found

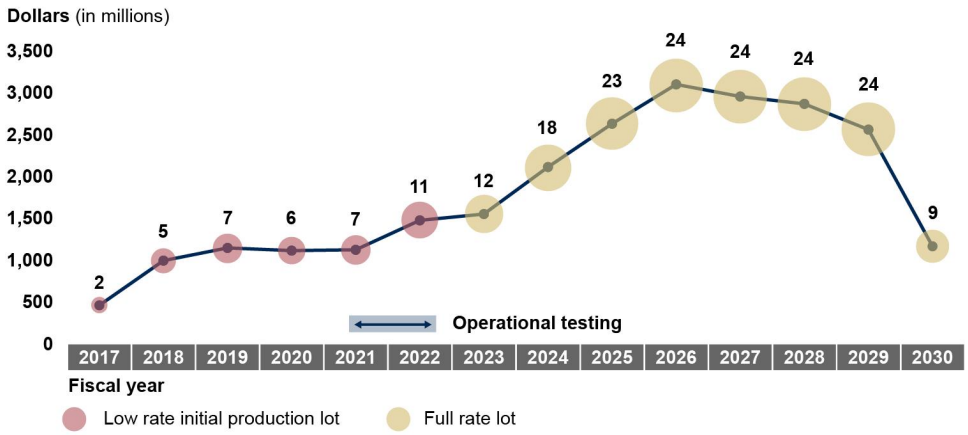
Fifteen years into development, the CH-53K program has made progress in testing the aircraft. Program documentation indicates that there is a moderate risk of not demonstrating the required levels of reliability or payload carrying weight by the end of operational testing.

The technical issues identified during testing caused program milestones to slip. For example, the full-rate production decision was delayed by nearly 7 years—from December 2015 to November 2022. CH-53K total program costs also increased by nearly $15.3 billion since the program began due to technical issues and a quantity increase fielded helicopters from 156 to 200.

The program faces several challenges going forward.

- First, the schedule for completing the development of the CH-53K does not meet all of the leading practices, which makes the schedule unreliable. Specifically, GAO found that the master schedule is not fully credible or well-constructed. For example, the schedule indicates there is more flexibility in the schedule than it truly has, which can affect the ability to change allocated resources appropriately to meet schedule milestones.
- Second, the program faces potential further cost increases due to concurrency—or overlap between testing and procurement—which has increased due to delays in the completion of testing. In previous reviews of weapon systems, GAO found that while some concurrency is understandable, it can also result in cost increases and schedule delays, and deny timely, critical information to policy makers. Concurrency, coupled with plans for increased numbers of helicopters to be produced, beyond the six per year currently being built, could result in costly retrofits to helicopters built before the completion of operational testing. This testing will provide decision makers needed information on the resolution of the technical issues facing the program (see figure).

CH-53K Helicopter Testing and Procurement, Fiscal Years 2017-2030



Source: GAO analysis of December 2019 Selected Acquisition Report and program office documents. | GAO-21-208

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Data table for CH-53K Helicopter Testing and Procurement, Fiscal Years 2017-2030

FY Year	Testing and Procurement Amount (in millions of dollars)
2017	492.6
2018	1026.6
2019	1178.5
2020	1146.4
2021	1156.2
2022	1508.2
2023	1583.6
2024	2145.5
2025	2663.3
2026	3133.4
2027	2988.3
2028	2900.5
2029	2592.7
2030	1197.8

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Abbreviations

CPIF	cost-plus-incentive-fee
DCMA	Defense Contract Management Agency
DOD	Department of Defense
DOT&E	Director, Operational Test and Evaluation
FPI	fixed-price incentive
KPP	key performance parameter
MFHBOMF	Mean Flight Hours Between Operational Mission Failures
MRL	Manufacturing Readiness Level
NAVAIR	Naval Air Systems Command
OMF	operational mission failure
SDTA	System Development Testing Article

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March 4, 2021

The Honorable Donald Norcross
Chairman
The Honorable Vicky Hartzler
Ranking Member
Subcommittee on Tactical Air and Land Forces
Committee on Armed Services
House of Representatives

The United States Marine Corps uses heavy lift helicopters to meet its need for moving heavy equipment, such as vehicles and artillery. The Marine Corps is facing a critical shortage of Marine Corps heavy lift aircraft, currently met by the CH-53E helicopter. The CH-53E is an aging helicopter design that cannot meet current or expected needs, and it has recently experienced maintenance and supply challenges.[1] To address anticipated near-term heavy lift requirements, among other missions, the Marine Corps initiated the CH-53K Heavy Lift Replacement program in 2005. The CH-53K helicopter is intended to transport armored vehicles, equipment, and personnel to support operations deep inland from ships. Because the Marine Corps operates within the Department of the Navy, the Navy is leading the acquisition of the CH-53K.

Since 2005, the program has experienced significant cost overruns and schedule delays due, in part, to technical challenges identified during developmental testing. In 2011, we reported that the CH-53K program began development before officials determined how to achieve requirements within the program's schedule and planned budget.[2] We also found that miscommunication between the program office and the prime contractor regarding systems engineering tasks, among other factors, led to a developmental cost growth of over $1.7 billion (39 percent) and delayed preliminary design review by over a year.

You requested that we review the CH-53K program. This report examines the program's (1) progress toward completing testing and demonstrating

[1]GAO, *Weapon System Sustainment: Aircraft Mission Capable Rates Generally Did Not Meet Goals and Cost of Sustaining Selected Weapon Systems Varied Widely,* GAO-21-101SP (Washington, D.C.: Nov. 19, 2020).

[2]GAO, *Defense Acquisitions: CH-53K Helicopter Program Has Addressed Early Difficulties and Adopted Strategies to Address Future Risks*, GAO-11-332 (Washington, D.C.: Apr. 4, 2011).

system performance; (2) schedule and cost experience to date; and (3) potential future challenges.

To assess progress the program has made in developmental testing and demonstrating system performance goals, we reviewed test event progress and schedules and program briefings, including briefings to Congress. We analyzed program documentation and updates on identified deficiencies. We also interviewed Department of Defense (DOD) officials and representatives from Sikorsky Aircraft Corporation regarding the deficiencies and resolution time frames. To assess the program's progress toward performance goals, we compared the program's stated capability goals with test results. In addition, we interviewed program officials and developmental and operational test officials about known technical problems that could affect stated capability goals. To provide information on operational testing, we reviewed the planned operational test schedule. We also interviewed program officials and independent test officials.

To assess the schedule and cost experience to date, we compared the program's approved baselines at the start of the program (2005), the 2017 Milestone C decision approving the start of production, and the latest estimates (2020 for schedule and 2019 for cost). We used estimated dates based on available data and then-year dollars unless otherwise indicated. These data were contained in selected acquisition reports (2005-2019) and briefings provided by the program office and Sikorsky Aircraft Corporation. We also examined and analyzed key acquisition documents, including contractor monthly status reports from January 2020 to April 2020, and Defense Contract Management Agency (DCMA) reports from January 2020 to November 2020 on technical deficiencies, production, and cost. To determine the reasons for these changes, we analyzed selected acquisition reports and interviewed program officials and contractor representatives.

To assess the program's future challenges associated with the production line and the program's ability to meet future schedule and cost targets, we collected and analyzed production performance data from the program office and Sikorsky, the prime contractor. We analyzed the extent to which the program has met GAO identified manufacturing leading

practices.[3] We also reviewed DCMA's monthly reports from January 2020 to November 2020. In addition, we compared the program office's portion of the development phase of the integrated master schedule—a time-based schedule containing the detailed tasks needed to achieve program and contract execution—to leading practices in GAO's schedule guide.[4] An integrated master schedule provides a time sequence for the duration of a program's activities and helps managers understand both the achievability of major milestones and the activities that drive the program's schedule. A well-planned schedule is a fundamental management tool that can help acquisition programs use funds effectively by specifying when work will be performed in the future and measuring program performance against an approved plan. We provided our criteria and draft analyses to the program office for review and incorporated their technical comments as appropriate.

For all objectives, we assessed the reliability of the data and found them sufficiently reliable for the purposes of reporting cost, schedule, test events, performance outcomes, and production readiness. We assessed the reliability of the earned value management data by reviewing existing information about the data and the system that produced them, and interviewing knowledgeable officials from DCMA and Sikorsky about the data. While we found that the data are sufficiently reliable for our purposes, we did observe some limitations due to a data black out period where the program office and prime contractor revised the master schedule. Due to this limited data, we did not directly report on the earned value management data, but rather used the data to identify areas of concern.

We conducted this performance audit from January 2020 to March 2021 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.

[3]GAO, *Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed*, GAO-10-439 (Washington, D.C.: Apr. 22, 2010).

[4]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

Background

The Navy began the CH-53K development program in 2005 to replace the aging CH-53E helicopter with a helicopter that can provide needed capabilities in the combat assault transport of heavy weapons, equipment, and supplies from sea to support Marine Corps operations ashore. The CH-53K design is an evolution of the CH-53E and was intended to take up the same amount of space on a ship while providing significant lift, reliability, maintainability, and life-cycle cost improvements. Some of the major improvements include upgraded engines, replacement of mechanically actuated flight controls with electronic versions, improved cargo handling and capacity, and survivability and force protection enhancements. The helicopter is designed to, at a minimum, be able to transport external loads over 27,000 pounds over a range of 110 nautical miles at 91.5 degrees Fahrenheit at an altitude of 3,000 feet—a Navy operational requirement for high-hot conditions— without refueling, and to fulfill land- and sea-based heavy lift requirements, which is a major performance improvement over the CH-53E.

Table 1 compares capabilities and characteristics of the CH-53E with the projected capabilities and characteristics of the CH-53K.

Table 1: Comparison of the CH-53E and CH-53K Capability Projections

Capabilities and characteristics	CH-53E (actual)	CH-53K (projected)
Empty weight—represents the weight of the helicopter without any payload, fuel, or fixed useful load.	37,500 pounds	44,659 pounds
Maximum distance—represents the maximum distance the helicopter can travel without receiving aerial refueling.	580 nautical miles	490 nautical miles
Maximum speed—represents the maximum speed the helicopter can achieve at sea level in standard conditions.	172.5 miles per hour	172.5 miles per hour
Maximum internal weight—represents the maximum weight that the helicopter can hold inside the fuselage.	15,000 pounds	18,000 pounds
Maximum external weight (high-hot)—represents the maximum weight that the helicopter can haul externally outside the fuselage at the Navy operational requirement for high-hot conditions (91.5 degrees Fahrenheit at an altitude of 3,000 feet).	8,265 pounds	36,000 pounds
Maximum gross weight—represents the total maximum weight of the helicopter including cargo and the helicopter itself.	73,500 pounds	88,000 pounds

Source: GAO and program office officials. | GAO-21-208

While the Marine Corps is the intended user of the CH-53K, it works with the Navy, through its Naval Air Systems Command (NAVAIR), to develop it. Specifically, the Marine Corps Headquarters conducts budget planning

and establishes priorities for the CH-53K program office, while NAVAIR is responsible for procuring and supporting U.S. Navy and Marine Corps aircraft and weapons. NAVAIR is responsible for the formal processes for development, procurement, fielding, and support.

CH-53K Development and Procurement Contracts

The Navy awarded Sikorsky a sole-source contract to develop the CH-53K helicopter. According to the program office, Sikorsky, as the developer of the CH-53E, was the only known qualified source with the ability to design, develop, and produce the required CH-53 variant. Sikorsky's contract was modified to include the development and demonstration phase for the replacement CH-53K helicopter—referred to as the development contract—in 2006.[5] As a part of the development contract and to support developmental testing, the program procured one helicopter (delivered in 2012) to use for ground tests and four engineering development model helicopters (delivered in 2016). As we have previously reported, technical problems have extended the development performance period well beyond original projections.[6]

In addition to the engineering development models, the program also modified the sole-source contract to procure four System Development Testing Article (SDTA) helicopters to prove manufacturing capability and support initial operational testing. These four developmental helicopters count toward the Marine Corps' defined need of 200 operational CH-53K helicopters to be fielded. The program originally planned to purchase six SDTAs, but due to funding limitations deferred two helicopters to be

[5]The contract line item for the system development and demonstration phase was priced on a cost-plus-award-fee basis. A cost-plus-award-fee contract is a cost-reimbursement contract that provides for a fee consisting of (a) a base amount (which may be zero) fixed at inception of the contract, and (b) an award amount, based upon a judgmental evaluation by the government, sufficient to provide motivation for excellence in contract performance. In April of 2011, a modification to the development contract converted the line item to Cost-Plus-Incentive-Fee (CPIF) pricing. A CPIF contract reimburses the contractor for its allowable costs, but still uses a formula of total allowable costs to target costs to determine fee and includes a target fee instead of a target profit. A CPIF contract also has a minimum fee—the lowest fee the contractor may receive when total allowable costs exceed target costs—and maximum fee—the highest fee the contractor may earn when total allowable costs are less than target costs.

[6]GAO, *Weapon Systems Annual Assessment: Limited Use of Knowledge-Based Practices Continues to Undercut DOD's Investments*, GAO-19-336SP (Washington, D.C.: May 7, 2019); and *Weapon Systems Annual Assessment: Knowledge Gaps Pose Risks to Sustaining Recent Positive Trends*, GAO-18-360SP (Washington, D.C.: Apr. 25, 2018).

procured during production. Table 2 summarizes the planned quantities of helicopters.

Table 2: Planned Acquisition Strategy for CH-53K by Procurement Category

Procurement category	Ground Test Vehicle	Engineering Development Model	System Demonstration Test Article	Low Rate Initial Production	Full Rate Production
Number of helicopters	1	4	4	38	158
Operational helicopters to be fielded	--	--	Yes	Yes	Yes

Source: CH-53K program office documents. | GAO-21-208

As of October 2020, the program has modified its contract with Sikorsky to include the first four low-rate production lots for 20 helicopters, with a total value of about $3.8 billion.[7] The program is currently planning for two additional low-rate initial production awards for 18 additional helicopters—acquiring a total of 38 helicopters through the six low-rate production lots. The program office released a solicitation for low rate lots 5 and 6 and according to a program official, received the proposal in January 2021.

Developmental and Operational Testing

We have previously reported that test and evaluation activities are an integral part of developing and producing weapon systems, as they provide knowledge of a system's capabilities and limitations as it matures and is eventually delivered for use by the warfighter.[8] Testing activities may be developmental or operational in nature and include live fire testing.

[7]Low-rate initial production establishes the initial production base for the system, provides an efficient ramp-up to full-rate production, and maintains continuity in production pending operational test and evaluation completion. The four contracts were Fixed-Price Incentive (Firm Target) (FPI) contracts. An FPI contract specifies a target cost, a target profit, a price ceiling (but not a profit ceiling or floor), and a profit adjustment formula. These elements are all negotiated at the outset. The price ceiling is the maximum that may be paid to the contractor except for any adjustment under other contract clauses. When the contractor completes performance, the parties negotiate the final cost, and the final price is established by applying the formula. For additional information on FPI, see GAO-21-181: *Fixed-Price-Incentive Contracts: DOD Has Increased Their Use but Should Assess Contributions to Outcomes* (Washington, D.C.: Feb. 3, 2021).

[8]GAO, *DOD Operational Testing: Oversight Has Resulted in Few Significant Disputes and Limited Program Cost and Schedule Increases*, GAO-15-503 (Washington, D.C.: June 2015).

Developmental testing, which is conducted by contractors, university and government labs, and various DOD organizations, is intended to provide feedback on the progress of a system's design process and its combat capability as it advances toward initial production or deployment.

Initial operational test and evaluation—or operational testing— is managed by the various military test organizations representing the customers, such as combat units that will use the weapons. It is intended to evaluate a system's effectiveness and suitability under realistic combat conditions before full-rate production or deployment occurs. According to the Director, Operational Test and Evaluation (DOT&E), operational testing frequently identifies new and significant problems missed in earlier program development, but it can also find issues known prior to testing that were unaddressed. The latter category can be especially problematic, as delays in addressing these problems can increase the cost and time required to fix them.

Operational effectiveness is the system's overall degree of mission accomplishment when used by representative personnel (e.g. warfighters) in the environment planned or expected for operational employment of the system considering organization, training, doctrine, tactics, survivability or operational security, vulnerability, and threat. Operational suitability is the degree to which a system can be satisfactorily placed in field use, with consideration given to reliability, transportability, interoperability, and safety, among other attributes.

Major defense acquisition programs, such as the CH-53K program, may not proceed to full rate (or beyond low-rate) until initial operational testing and evaluation is completed and the congressional defense committees have received the report of testing results from the DOT&E. This report is to contain an opinion about test and evaluation adequacy and whether the test and evaluation results confirm that the system actually tested is operationally effective and suitable for combat.[9]

Under **live fire testing**, as the name indicates, the air vehicle and its systems are exposed to gunfire and other weapons fire to determine how the aircraft will perform and assess its survivability. It is an assessment of the vulnerability and lethality of a system as it progresses through developmental testing prior to the full-rate decision. This testing will provide information to decision makers on potential user casualties,

[9]10 U.S.C. section 2399(b)(2).

vulnerabilities, and lethality. Realistic survivability testing is a measure of a system's vulnerability to munitions likely to be encountered in combat. Realistic lethality testing is a measure of a system's ability to combat intended targets.

Alternative Fleet Structure and Marine Corps Restructuring Studies

DOD has conducted various studies to determine the mix and number of aircraft it would take to satisfy Marine Corps heavy lift requirements.

- **Analysis of Alternatives:** The Marine Corps completed an Analysis of Alternatives in 2003 to determine a heavy lift replacement aircraft. The Marine Corps initially considered seven existing aircraft platforms, but decided to focus on a modified version of the CH-53E platform.
- **Heavy Lift Helicopter Requirement Analysis:** In 2008, the Marine Corps increased the total number of CH-53K required from 156 to 200 without conducting an analysis justifying the change. At the recommendation of the Navy Inspector General, the Marine Corps conducted a study on the procurement quantity increase, and found that the increase in procurement levels was necessary based on the need for additional heavy lift capability. The study stated while it would take 220 CH-53K aircraft to fully support heavy lift missions through fiscal year 2059, the Marine Corps accepted the risk associated with the current plan for procuring 200 helicopters due to budgetary pressures.
- **CH-53K/CH-47F Block II Mix study:** In 2020, the Office of the Secretary of Defense's Cost Assessment and Program Evaluation office, in collaboration with the Marine Corps, conducted a study to determine if a fleet of CH-47F Block II and CH-53Ks could be a viable replacement to the current CH-53K procurement strategy.[10] The study examined a number of different scenarios and found that a fleet consisting of just CH-47Fs and a fleet consisting of both CH-53Ks and CH-47Fs would cost less to procure and operate than the currently planned fleet of CH-53Ks. However, while the mixed fleet of aircraft could complete most missions, the missions would take longer

[10]The CH-47 Chinook is a twin-engine, tandem rotor helicopter manufactured by Boeing and used by the United States Army. The CH-47F Block II variant program began in 2017 to replace the CH-47Fs. The Army intends for the upgraded aircraft to provide additional capability, greater reach, and increased payload capacity through 2060.

because the CH-47F cannot carry as much weight as the CH-53K and as a result would require more trips to complete the mission. In addition, the CH-47Fs cannot lift some of the heavier equipment, such as the Joint Light Tactical Vehicle.[11]

- **Force Design study:** The Marine Corps released a restructuring plan in March 2020 that recommended a reduction in the number of heavy lift squadrons, from eight to five, due to a projected reduction in the number of required Marines. This may affect the number of helicopters that are procured. According to program officials, a decision is expected to be released in February 2021 with any changes to the existing program of record reflected in the fiscal year 2023 budget request.

Progress in Completing Developmental Testing, Which Identified Key Technical Issues and Delayed Start of Operational Testing

Technical issues identified during developmental testing have delayed the start of operational testing, resulted in the extension of the development contract period of performance, and put the program at risk of not meeting some performance goals. Most developmental flight tests needed to start operational testing have taken place, albeit later than planned. The program is now slated to start operational testing in June 2021—about 2 years later than scheduled when the program entered production.

After Years of Delay, Core Developmental Testing Nearly Complete

Developmental testing is ongoing, but many of the significant test events have been completed.[12] The program has identified core flight test events within the developmental testing program that must be completed before

[11]Joint Light Tactical Vehicle is a family of vehicles designed to provide protection for passengers against current and future battlefield threats and increased payload capacity over the previous vehicles it is replacing.

[12]Developmental testing is intended to provide feedback on the progress of a system's design process and its combat capability as it advances toward initial production or deployment.

operational testing can begin and, according to the program office and the contractor, the program has completed nearly all of those events. According to the program office, as of November 2020, the program had completed 1,545 out of the 1,622 planned developmental flight test events and expects to complete the needed test events to support initial operational test and evaluation by February 2021.[13] When the program entered production in 2017, program officials had expected to complete developmental testing by 2019 but had to extend the program by about 2 years because the technical issues discovered during developmental testing required more time for component redesigns, re-qualifications, and retests. In addition, the development contract period of performance was extended from ending in April 2020 to ending in May 2025.

After initial operational testing is completed, the program plans to conduct additional developmental testing to ensure that all of the technical challenges are resolved. In some cases, developmental testing has identified technical issues that have led to restrictions in how the CH-53K can be operated—such as by limiting the amount of weight it can lift, altitudes at which it can fly, or environmental conditions in which it can fly. In particular, according to program documentation, the program plans to conduct an additional 623 developmental flight test events to validate the expansion of the helicopter performance parameters as restrictions are lifted.[14]

In addition, the DOT&E approved Live Fire Test and Evaluation program included two phases. According to a live fire test official, about half of the tests for the first phase of live fire testing have been completed. While the program temporarily stopped Phase I testing in fiscal year 2019 due to a reallocation of funding, according to the live fire test official, testing resumed in April 2020. According to this official, these tests are scheduled to be completed in October 2021. To support the initial production decision, DOT&E reported that a preliminary assessment of results indicated that the CH-53K is more survivable than the CH-53E.

Phase II of the testing program would evaluate the survivability of the aircraft against more challenging, but still operationally relevant threats. DOT&E reported phase II of testing is essential for an adequate

[13]According to DOT&E officials, the program uses test events to track testing. Each test event may consist of one or more individual test points.

[14]This is referred to as a flight envelope. The flight envelope includes the aircraft's performance limitations and design capabilities with respect to its altitude, airspeed, and acceleration.

survivability assessment of this helicopter in operationally realistic conditions. According to the live fire test official, the second phase of live fire testing is planned as follow-on operational test and evaluation, occurring after the initial operational test and evaluation testing being performed to support the full-rate production decision. The program has not yet received funding for the second phase of live fire testing, but according to program officials, funding for Phase II will be requested if the Marine Corps determines testing to objective threats is necessary.

Technical Issues Identified During Developmental Testing Could Affect Sustainability, Putting Mission Reliability Performance Goals at Risk

As of November 2020, the program had identified 126 technical deficiencies or issues. According to program officials, these issues were either identified by the contractor during its development efforts or by the government through flight testing and represent areas of concern such as lower than expected life of components, ease of maintenance, or manufacturing producibility. According to program officials, these technical issues are not ranked in order of importance, since each technical issue needs to be resolved for the helicopter to perform as desired. At a higher level, some of these technical issues can affect the helicopter's airworthiness—the helicopter's ability to safely attain, sustain, and terminate a flight within approved usage limits—as well as sustainment costs, or performance of the helicopter. Figure 1 shows key technical issues and their potential effect on the helicopter.

Figure 1: Overview and Location of Several Selected Technical Issues on the CH-53K Helicopter

	Affects	Path forward		Affects	Path forward
1 **Exhaust gas reingestion (EGR)** EGR occurs when the aircraft's engines intake hot engine exhaust gases while flying, which can make the engine overheat and shut off. There are other related technical issues, such as exhaust gas impingement on the skin of the aircraft and engine bay overheating.	$ ✳	✓	2 **Main gearbox (MGB)** A part of the transmission of the helicopter that helps transfer energy from the engines to the main rotor blades. The MGB was experiencing more than anticipated friction which was damaging the gears within the system.	$	✓
3 **Main rotor dampers** A component within the main rotor system that helps reduce vibration in the system. The dampers were experiencing overheating because of pressure spikes.	$	✓	4 **Power distribution unit (PDU)** The PDU distributes power to the different systems on the helicopter. The program discovered that the initial PDU design had the potential to have a single point failure causing important systems to lose power.	✳	✓
5 **Tail rotor flexbeam** The component that connects the tail rotor hub to the individual blades. The early flexbeam designs were delaminating during flight tests.	$	✓	6 **Wheel brake system** The wheel brake system is experiencing higher than expected hydraulic backpressure which is causing brake dragging.	✳	✓

$ affects the operating and support cost of the helicopter

✳ affects the performance of the helicopter

✓ a solution has been identified and is being tested

✓ a temporary solution will be used for operational testing while a permanent solution is investigated

Source: GAO analysis of program office documentation and officials (data and image). | GAO-21-208

The program plans to finalize and test the solutions to all 126 of the already identified technical issues and to any other technical issues that are potentially identified during operational testing prior to the full deployment of the helicopter to the warfighter, planned for fiscal year 2024.

According to program office documents, two of the eight key performance parameters—mission payload and mission reliability—are currently at moderate risk of not being achieved by the end of operational testing (see table 3).

Table 3: CH-53K Status of Meeting Key Performance Parameters (KPP)

Characteristic KPP	Threshold requirement	Current status	Program's risk that KPP will not be achieved by end of operational testing
Mission Reliability[a]	≥89 percent	84.5 percent	Moderate
Mission Payload[b]	≥27,000 pounds	27,088 pounds	Moderate
Net Ready[c]	100 percent	100 percent	Low
Sortie Generation Rate[d]	≥2.6 per day	2.6 per day	Low
Logistics Footprint (weight)[e]	≤110,122 pounds	83,950 pounds	Low
Logistics Footprint (size)[e]	≤15,577 cubic feet	12,708 cubic feet	Low
Survivability[f]	≤100 percent	97.8 percent	Low
Force Protection[f]	≥100 percent	100.8 percent	Low

Source: CH-53K program office documents and officials. | GAO-21-208

[a]Mission Reliability is the probability that the CH-53K will successfully complete a defined mission with an average sortie duration of 2.25 flight hours.

[b]The CH-53K shall be capable of conducting an unrefueled mission of 110 nm radius with a 27,000 lbs. external payload.

[c]The Net Ready measure consists of verifiable performance measures and associated metrics required to evaluate the timely, accurate, and complete exchange and use of information to satisfy information needs for a given capability.

[d]Sortie Generation Rate is the number of sorties required per helicopter to accomplish a specific mission given the total sorties required and the number of helicopters on hand.

[e]The Logistics Footprint is based on operations aboard an L-class amphibious assault ship and shall be less than or equal to the CH-53E Logistics Footprint.

[f]Survivability and Force Protection values are classified and have been rationalized for unclassified tracking.

The mission payload parameter is currently being met, but program officials are concerned that additional design changes may increase the weight of the helicopter. If this happens, the helicopter may not be able to meet the requirement to carry at least 27,000 pounds of mission payload. However, the current estimate for mission reliability is still below the

required threshold (i.e., minimally acceptable) requirement. The program office reported in November 2020 that the helicopter demonstrated an 84.5 percent reliability rate, which is short of the program's threshold requirement and below where the program office expected the reliability to be at this point in development.[15] The program office projects that the helicopter should reach mission reliability of 88.6 percent after operational testing.[16] According to program officials, the main causes of the reliability shortfalls have been technical issues identified during developmental testing. For example, the reliability of the main gearbox has been one of the main factors affecting the helicopter's overall mission reliability metric.[17] As mentioned, the program office has mitigation plans in place to address many of those technical issues, but has not yet demonstrated the required level of overall helicopter mission reliability.

A weapon system's reliability directly affects a warfighter's ability to complete a mission, and how much DOD must spend to operate and support the weapon system over its lifetime, which often spans decades. Poor reliability can negatively affect the warfighter through low operational availability; that is, the amount of time a system is available to execute its mission. Reliability can significantly influence a weapon system's operating and support costs, which we have previously reported can account for approximately 70 percent of a weapon system's total life-cycle cost.[18] Operating and support costs are a reflection of how programs achieve operational availability for weapon systems. Programs can achieve operational availability by building highly reliable weapon systems or, if the systems are not highly reliable, supporting them with an extensive logistics system that can ensure spare parts and other support

[15]The reliability measures reported by the program office in November 2020 are based on data collected from March 2020.

[16]Program office projections take into account technical fixes that have been designed but not yet installed or tested on the aircraft.

[17]Mission Reliability is calculated using the metric Mean Flight Hours Between Operational Mission Failures (MFHBOMF), which is the average number of flight hours between operational mission failures (OMF). An OMF results in a loss of capability to perform one or more mission essential functions during the mission. The more OMFs that the aircraft experiences during testing, the higher the MFHBOMF value and the lower the Mission Reliability value.

[18]GAO, *Defense Acquisitions: Senior Leaders Should Emphasize Key Practices to Improve Weapon System Reliability,* GAO-20-151 (Washington, D.C.: Jan. 14, 2020); and *Weapon System Sustainment: Selected Air Force and Navy Aircraft Generally Have Not Met Availability Goals, and DOD and Navy Guidance Need to Be Clarified,* GAO-18-678 (Washington, D.C.: Sept. 10, 2018).

items are available when needed. DOD has previously reported that deficiencies in DOD weapon systems—such as high failure rates and an inability to make significant improvements in reliability—have historically limited program performance and increased operating and support costs.[19]

Currently, the helicopter meets the minimum requirements in five of the eight reliability and maintainability goals, though according to program officials, they are striving to improve all of those metrics. The program office projected that the helicopter is at risk of not meeting the threshold level on two of its eight reliability and maintainability goals at maturity, which according to the program office is defined by having a cumulative 60,000 flight hours. The program expects to reach maturity in 2030, which is past the date for the full-rate production decision (see table 4).

[19]DOD Report of the Defense Science Board Task Force on Developmental Test and Evaluation (May 2008).

Table 4: Comparison of Current and Projected CH-53K Reliability and Maintainability Metrics, as of November 2020

Metric	Contractually required	Program's current status	Program's projected status[a]
Mean flight hours between failure—measures the average flight hours between unscheduled maintenance events requiring equipment corrective action or repair.	Metric is contractually required	Metric is below threshold metric	Metric is below threshold metric
Mean flight hours between built-in-test false alarms—measures the average number of flight hours the helicopter will fly before the helicopter's diagnostics will indicate a failure when none has occurred.	Metric is contractually required	Metric is below threshold metric	Metric is below threshold metric
Mission reliability—measures the probability of successfully completing a mission of average duration. This metric is also a key performance parameter.	Metric is contractually required	Metric is below threshold metric	Metric is at or above objective metric
Mean corrective maintenance time for operational mission failure—measures the average elapsed corrective maintenance time needed to repair all operational mission hardware failures.	Metric is contractually required	Metric is at or above threshold metric	Metric is at or above objective metric
Mean time to repair—measures the average elapsed corrective maintenance time needed to repair all chargeable failures.	Metric is contractually required	Metric is at or above objective metric	Metric is at or above objective metric
Maintenance man-hours per flight hour organizational—measures the average man-hours needed to maintain the helicopter at required readiness levels.	Metric is contractually required	Metric is at or above objective metric	Metric is at or above objective metric
Percent of correct built-in-test failure detections—measures the probability that built in test will correctly detect a system failure when one has occurred.	Metric is contractually required	Metric is at or above objective metric	Metric is at or above objective metric
Percent of correct built-in-test failure isolations—measures the probability that a correctly detected failure will be isolated to a single Weapons Replaceable Assembly either directly or through the use of prescribed maintenance procedures.	Metric is contractually required	Metric is at or above objective metric	Metric is at or above objective metric

Legend:

●: Metric is at or above objective metric

◓: Metric is at or above threshold metric

○: Metric is below threshold metric

✓: Metric is contractually required

Source: CH-53K program documentation and program officials. | GAO-21-208

[a]Projected status depicts helicopter performance based on the current planned fixes, rate of discovery of new modes, and rate at which failures are being fixed. The projected status is based on the program office reaching this status by maturity, which according to program officials is 60,000 flight hours expected to be reached in 2030.

Contractually, the helicopter needs to meet all mission reliability metrics by the full-rate production decision. According to the program's assessment, the helicopter is currently not on target to meet all eight of the reliability metrics by the full-rate decision, which is scheduled for November 2022. For example, mean flight hours between failure and mean flight hours between built-in-test false alarms. Meeting the reliability

and maintainability requirements are a critical step in reducing the risk of operating and support cost growth of the helicopter. According to GAO leading practices, the program should be able to demonstrate high reliability of the system before full-rate production because that indicates the design is stable and minimizes risk, helping ensure that the manufactured systems do not have to undergo potentially costly retrofits to fix reliability and maintainability problems.[20] The program's planned initial operational test and evaluation of the helicopter, expected to end in 2022, will give insight into the reliability of the system—providing policymakers useful information to consider before committing to an increased rate of procurement.

Operational Testing Delayed as Program Has Worked to Address Technical Issues

To start operational testing, the program has determined that it must verify the steps to address 106 of 126 technical issues that the program identified during developmental testing, because, according to program officials, these issues could affect the helicopter's ability to be determined operationally effective and suitable. As of October 2020, the program office stated that for those 106 issues: 75 have solutions closed, 30 are pending verification, and one has a solution being developed.[21] Program officials also stated that the program is on track to have fixes for all 126 issues verified and closed prior to the first deployment in fiscal year 2024.[22]

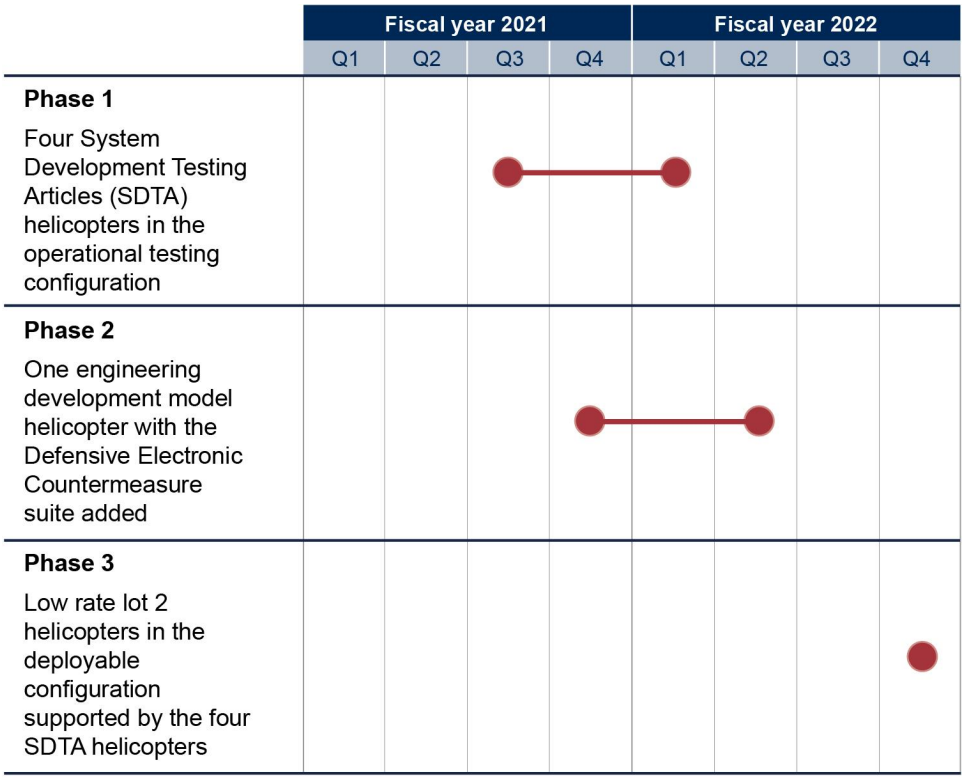
Operational testing, which is slated to begin in June 2021—2 years later than scheduled once the program entered initial production—will consist of three phases. Each phase will test additional capabilities and features of the helicopters. Figure 2 shows the timing and configuration of the helicopters being tested.

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

[21]According to the program office, "closed" refers to the solution design being finalized on paper, while "verified" means that the solution has been tested on the aircraft and found to be effective.

[22]Sikorsky's modified delivery date is May 2025 to resolve these 126 issues and integrate them onto the aircraft.

Figure 2: Schedule and Configuration of the Three Phases of Operational Testing for the CH-53K



Source: GAO analysis of CH-53K program office documentation and program officials. | GAO-21-208

According to program officials, each aircraft that will be used for operational testing could be considered a deployable configuration—a configuration that the Marine Corps can use to support heavy lift missions; however, this configuration will not have all of the required components and capabilities planned at program maturity. For example, the helicopters being used at the beginning of operational testing will not have satellite communications installed. Additionally, the helicopters will not have the embedded Terrain Avoidance Warning System software installed in time for operational testing, which is a key capability of the helicopter.[23] According to program officials, this software is expected to be installed in 2023, after initial operational testing. Program officials consider these helicopters to be deployable. In addition, program officials stated the helicopters should have all of the required components and

[23]The embedded Terrain Awareness Warning System is a required alerting system software that improves situational awareness and includes a digital color moving map.

capabilities prior to when the Marine Corps plans on deploying them in fiscal year 2024.

Addressing Technical Issues Has Contributed to Significant Program Milestone Delays and Cost Increases

The CH-53K program milestones have slipped and its total acquisition cost estimate has significantly increased since the program started in December 2005. These schedule delays and cost increases are, in part, due to quantity changes, but are also the result of management challenges and technical issues discovered during developmental testing.

Program Milestones Have Been Delayed

Management challenges and technical issues identified during testing drove schedule delays in the CH-53K program. In 2011, we reported that the program's schedule delays and development cost growth (then more than 39 percent) were the result of the program beginning development:

- without first determining how to achieve requirements within program schedule and cost constraints;
- with miscommunication between the program office and the prime contractor about system engineering tasks; and
- without the program office and the prime contractor being adequately staffed initially, as the program office was unable to add enough staff due to budget-driven hiring restrictions. Sikorsky also underestimated the time needed to locate, recruit, train, and assign qualified personnel.[24]

Subsequently, technical challenges discovered during developmental testing caused additional delays. As a result, the program now plans to deliver initial capability to the warfighter in September 2021, 6 years later than originally planned.[25] However, according to the latest program

[24]GAO-11-332.

[25]The Marine Corps defines initial operational capability as delivery of the first four fleet helicopters with required support equipment, technical publications, and trained aircrew and maintenance personnel, including initial spares with interim repair support in place.

schedule, delivery of the initial capability will be a year before the helicopters have been fully tested and proven in an operational environment. We have previously reported that declaring initial operational capability in advance of testing increases the risk of cost growth and schedule delays.[26] According to Marine Corps officials, they plan to declare initial operational capability with the four SDTA helicopters. They further stated that even though some performance requirements will not be tested before declaring initial operational capability, this does not mean that the helicopter is not capable of meeting those performance requirements. In addition, they stated that there is time to test these capabilities prior to deployment. The program is scheduled to achieve first operational deployment in 2024, and be fully operationally capable in 2029.[27] According to program officials, operational deployment is when the Marine Corps will use the helicopter in overseas missions.

Table 5 compares the program's schedule for major program events at the start of development and production to the current schedule.

Table 5: Major CH-53K Program Events and Dates

Major events	Development start estimate (December 2005)	Production start estimate (December 2017)	Actual/latest estimate (August 2020)	Delay since development start
Development start	October 2005	December 2005	December 2005	2 months
Critical Design Review	March 2009	July 2010	July 2010	16 months
Initial production decision (Milestone C)	December 2012	March 2017	April 2017	52 months
Completion of Initial Operational Test and Evaluation	June 2015	December 2019	September 2022	87 months
Initial Operational Capability[a]	September 2015	December 2019	September 2021	72 months
Full-rate production decision	December 2015	September 2020	November 2022	83 months

Source: GAO analysis of Department of Defense schedule information based on selected acquisition reports and other program documentation. | GAO-21-208

[a]Initial operational capability is defined as delivery of the first four fleet helicopters with required support equipment, technical publications, and trained aircrew and maintenance personnel, including initial spares with interim repair support in place.

[26]GAO-19-336SP.

[27]Full operational capability is achieved when all maintenance and repair support, test equipment, and spares are in place and personnel are fully trained on the helicopter.

Program's Acquisition and Life-Cycle Costs Have Increased Significantly

The management and technical challenges that delayed the program schedule, along with quantity changes, increased program costs. As of December 2019, the Navy estimated that the CH-53K would cost about $15.3 billion more to develop and produce and about $29 billion more to operate and support the helicopters through fiscal year 2061 than the estimates first developed at the start of the program in 2005. In 2011, we reported that most of the $6.8 billion cost growth at that time was a result of an increase in the total number of helicopters from 156 to 200 (28.2 percent) in 2008 to support an increase in the Marine Corps' force strength from 174,000 to 202,000 Marines. This increase, among other factors, required the program to change both its development and procurement cost estimates.[28] Overall, the program's total estimated life-cycle costs—which include the estimated cost of operating and supporting the aircraft—have increased by about $44.7 billion, a 63 percent increase from the program's initial estimate.

Table 6 compares the program's current cost estimates with its baseline estimates from the start of the program and the start of production.

Table 6: Initial, Production, and Current CH-53K Heavy Lift Helicopter Program Cost Estimates (then-year dollars in millions)

	Initial estimate (December 2005)	Production estimate (December 2017)	Latest estimate (December 2019)	Percentage change from production estimate	Percentage change from initial estimate
Development	4,366.4	6,957.8	8,097.8	16.4	85.5
Procurement	14,399.9	24,263.3	25,925.2	6.9	80.0
Military construction	N/A	13.2	13.2	0	N/A
Total program acquisition cost	**18,766.3**	**31,234.3**	**34,036.2**	**9.0**	**81.4**
Operating and support	52,062.7	77,882.8	81,466.7	4.6	56.5
Total estimated life cycle cost	**70,829.0**	**109,117.1**	**115,502.9**	**5.9**	**63.1**

Source: GAO analysis of Department of Defense cost information based on selected acquisition reports. | GAO-21-208

Note: The total number of CH-53K helicopters to be procured increased from 156 to 200 (28.2 percent) in 2008 to support an increase in the Marine Corps' force strength from 174,000 to 202,000 Marines.

As of November 2020, DCMA reported that Sikorsky had completed about 84 percent of its planned work on the contracts that support the

[28]GAO-11-332.

development program. With approximately 16 percent of the development program remaining and many technical issues that are not yet resolved, there is potential for continued development cost growth. In reviewing a 2020 revised schedule for work under the development contract, Sikorsky and program officials identified development costs as high risk. Program officials stated that the primary contributor to the cost risk is not meeting air vehicle requirements, such as the brake system and engine protection system, which could require more funds to fix. Also driving the cost risk is insufficient management reserve—which means the program may not have enough time and money to complete the tasks necessary to finish the development effort within current schedule and cost targets. However, program officials have stated that they do not plan to add more funding to the development program and acknowledged that while they are not currently planning to scale back any capabilities to meet budget limitations, the program may need to do so in the future if the work cannot be completed within current developmental funding levels.

Procurement cost estimates grew by $1.6 billion (almost 7 percent) from fiscal year 2018 to 2019 due in part to cost increases in several areas. These include the systems engineering and program management estimates for the first initial production lot, award of the airframe production contract for the second and third initial production lots, increases in the cost of the engines, and the addition of two production helicopters to replace the last two SDTA helicopters that were originally to be bought with development funds.

Military construction cost estimates have remained relatively stable since the production decision in 2017. However, the program stated that it will need more funding to stand up depot military construction facilities for repair that the Marine Corps, through the Navy, plans to do in-house. According to a program risk assessment from 2020, if the military construction facility requirements are not funded within the upcoming years, there will not be sufficient in-house infrastructure for gearbox repair and testing and advanced composite repair. This would result in greater reliance on repairs by the suppliers of the gearbox—which would increase future costs for any helicopters that are down due to required gearbox repair—until the program is able to establish that in-house repair capability.

While procurement quantities have increased by about 29 percent, the total operating and support cost estimate has increased by more than 56 percent, or $29 billion, since its initial estimate. Engine reliability and software maintenance rates affected operating and support cost

estimates early on, while the current reliability projections we discussed above, in particular on the main gearbox, continue to affect the program's life-cycle costs.

Future Production Concerns, Program Schedule Challenges, and Rising Concurrency Raise Risks to Program

The CH-53K program faces a number of challenges as it proceeds into production. The prime contractor does not fully know the capabilities of its production line and faces issues with its supplier base. Furthermore, the program recently approved a new integrated master schedule for completing tasks leading up to operational testing that does not reflect leading practices. In addition, more concurrency has been introduced between development and production. The program has recently procured six helicopters per year, but expects to increase the annual procurement in coming years before the end of operational testing.

Unknown Production Capacity and Supplier Base Concerns Raise Risk for Future Cost Increases

Program officials have stated that the production line is nearing maturity, but this assessment does not fully reflect the contractor's current production capability. According to program officials, the production line is capable of producing 24 helicopters a year—the maximum level of production expected over the next 10 years. However, the program office's last assessment of the production line was in 2017, when the program entered initial production. Further, the assessment was not done on the actual production line that will be used to build the CH-53K, but rather on a previous line where the SDTA helicopters were built.

In addition, the production line has not yet reached metrics for maturity. When last assessed in 2017, the production line was not in statistical control—which is a technique for monitoring production processes to see if they are consistently producing output that is within the quality standards and tolerances set for the overall product. This approach was inconsistent with leading practices, which state that manufacturing and quality processes and procedures have been proven on a pilot line and are under control. In addition, the program assessed the production readiness at a level below the preferred level noted in DOD guidance. In

particular, when last assessed, the production line was at a Manufacturing Readiness Level (MRL) 7, while DOD guidance indicates a preference for programs to enter production at an MRL 8.[29] MRL 7 is typical for the mid-point of development and is when the manufacturing line can produce systems, subsystems, or components in a production representative environment. At MRL 8, the pilot line capability was demonstrated and the production line is ready to begin low-rate initial production. Further, the MRL 7 was based on an assessment of a Florida-based production line that produced the development helicopters. According to program officials, this line is responsible for retrofitting the SDTA helicopters, but subsequent production helicopters will be assembled on a Sikorsky production line in Connecticut, which opened in 2018. The Connecticut production line, on which 196 of the planned helicopters will be produced, has not been assessed to determine if the production line meets the criteria for MRL 8. The first helicopter to be delivered from this location is scheduled for September 2021.

In addition, deficiencies discovered in developmental testing have required the program to undertake design changes that, in some cases, have required changes to production line processes, which could affect the production readiness metrics. For example, according to program officials, the fix for the exhaust gas re-ingestion issue will require a metal plate on the helicopter to be relocated. This will require a change to the production process, which is one element in the assessment of production process maturity. In 2019, the program office reported that it had released 99 percent of CH-53K design drawings, which indicates a stable design. However, several parts have required redesigns since that time. For example, the tail rotor flexbeam has undergone three design changes. However, it may be further redesigned as its currently expected operational life of 2,800 hours is still short of the originally anticipated 10,000 hours, according to program officials.

Our prior work has repeatedly found that DOD programs that moved into production carrying manufacturing risks experienced cost growth in production and increases in their average procurement unit costs.[30] In addition, our previous report on manufacturing leading practices found

[29]Manufacturing Readiness Levels are a measurement scale designed to provide a common metric and vocabulary for assessing manufacturing maturity and risk. There are 10 basic manufacturing readiness levels.

[30]GAO- *F-35 Joint Strike Fighter: Actions Needed to Address Manufacturing and Modernization Risks*, GAO-20-339 (Washington D.C.: May 12, 2020); and GAO-10-439.

that achieving manufacturing maturity and identifying production risks early in the acquisition cycle and assessing those risks prior to key decision points, such as the decision to enter production, reduces the likelihood of quality issues, cost growth, and schedule delays.[31] The CH-53K program last conducted such an assessment in April 2017 but, as discussed above, that was prior to the relocation of the production line from Florida to Connecticut and a number of subsequent design changes. Program officials stated they will reassess the production line again to support the full-rate decision, which is currently scheduled for November 2022. This assessment will include information on the Connecticut production line's maturity and supplier base.

Further compounding the production problems are the ongoing concerns with the helicopter's supplier base. The program has faced challenges with poor quality of parts, suppliers not producing enough parts, and process problems, among others. These problems have resulted in delays to the production of the development helicopters. For example, the program did not have enough main gearboxes due to lower than expected quality and quantity of the part. As a result, Sikorsky took the parts planned for the fourth development helicopter and used them to complete the production of earlier helicopters. The program has also had low yield issues with a significant component of the helicopter's rotor blade. According to Sikorsky officials, while the supplier's yield has recently improved, it is still lower than expected.

While problems still exist with supply quality, Sikorsky has taken steps to help mitigate those issues. These include looking for additional suppliers, providing help to suppliers struggling with their production processes, and bringing some parts manufacturing in-house. For instance, Sikorsky officials stated that they helped one supplier by creating templates for and helping with automation of that contractor's related manufacturing process where possible. In other cases, Sikorsky officials stated that they are bringing some parts production in-house, such as one component of the main gearbox.

Despite the production issues, DCMA officials, program officials, and Sikorsky stated that they expect delivery of the first low-rate production lot of two helicopters to be delivered in the July to November 2021 period—a year later than previously planned—to incorporate changes needed to fix technical issues identified during testing. According to DCMA officials,

[31]GAO-10-439.

there may be continuing parts shortages experienced during future years of low-rate production. The program plans for a total of six low-rate production buys, with the most recent awarded annual procurement being for six helicopters.

Revised Plan for Development Does Not Fully Meet Leading Practices, Adding to Program Risk

The CH-53K integrated master schedule for the program's development phase, as revised in 2020, cannot be considered reliable, hindering decision making for the program and adding to program risk. In June 2020, the CH-53K program completed a review of its schedule to better align the remaining work on the development contract to reflect more realistic budget and schedule constraints. This integrated baseline review resulted in a new approved schedule of tasks. We reviewed the part of the schedule that relates to the developmental efforts that need to be completed prior to operational testing.

The CH-53K development schedule fully or substantially met five of 10 project scheduling leading practices and partially met five leading practices.[32] GAO's schedule guide identifies 10 leading practices for developing and maintaining reliable project schedules. These leading practices are grouped into four characteristics of a reliable schedule—comprehensive, controlled, well-constructed, and credible. In our assessment of the program's schedule, we found that the schedule was comprehensive and controlled, but partially credible and partially well-constructed. As a result, the project's schedule could not be considered reliable. A schedule provides a road map for systematic project execution and the means by which to gauge progress, identify and resolve potential problems, and promote accountability. The credibility of decision-making on a project will be negatively impacted if the schedule is not reliable.

Table 7 shows our assessment of the CH-53K schedule compared to leading practices.

[32]For the ratings described here, "partially met" means the project team provided evidence that satisfies about half of the criterion. "Substantially met" means the project team provided evidence that satisfies a large portion of the criterion. "Fully met" means the project team provided complete evidence that satisfies the entire criterion.

Table 7: Comparison of Development Schedule for the CH-53K Program to Leading Practices, as of November 2020

Characteristics of a Schedule	Overall GAO Assessment of Characteristics for Schedule	Leading Practices for Each Characteristic[a]	GAO Assessment of Leading Practices for Schedule[b]
Comprehensive	Substantially met	Capturing all activities	Substantially met
		Assigning resources to all activities	Fully met
		Establishing the durations of all activities	Substantially met
Controlled	Fully met	Updating the schedule using actual progress and logic	Substantially met
		Maintaining a baseline schedule	Fully met
Well-constructed	Partially met	Sequencing all activities	Partially met
		Confirming that the critical path is valid	Partially met
		Ensuring reasonable total float	Partially met
Credible	Partially met	Verifying that the schedule can be traced horizontally and vertically[c]	Partially met
		Conducting a schedule risk analysis	Partially met

Source: GAO analysis of information from CH-53K program. | GAO-21-208

[a]GAO, *Schedule Assessment Guide: Best Practices for Project Schedules*, GAO-16-89G (Washington, D.C.: Dec. 22, 2015).

[b]For the leading practice ratings described here, "partially met" means the project team provided evidence that satisfies about half of the criterion. "Substantially met" means the project team provided evidence that satisfies a large portion of the criterion. "Fully met" means the project team provided complete evidence that satisfies the entire criterion.

[c]A schedule with horizontal and vertical traceability accounts for the interdependence of detailed activities, and activities are traceable among various levels of the schedule.

Comprehensive. We found that the schedule substantially met the comprehensive characteristic. For example, the development project schedule followed leading practices by including activities for both DOD and its contractors that are necessary to accomplish the program's objectives. Further, all activities had work breakdown structure elements assigned that defined in detail the work necessary to accomplish a project's objectives. In addition, most activities included in the schedule identified the resources that were needed for completing the activity.

Controlled. We found that the schedule fully met the controlled characteristic. For example, the project schedule met leading practices by including a process for trained schedulers to update the schedule report monthly. In addition, program officials stated that changes to the baseline schedule go through a change control process in which management needs to review, approve, and document any changes.

Well-Constructed. We found that the development schedule partially met the well-constructed characteristic. According to GAO's schedule guide, a

schedule should be substantially or fully well-constructed in order to respond to changes and reliably predict dates. However, we found several issues related to the construction of the project's schedule, including (1) the sequencing of activities, (2) the schedule's critical path, and (3) the amount of float—the amount of time an activity can be delayed or extended before that delay affects the program's finish date—calculated in the schedule.

(1) Our assessment found issues with sequencing of activities in the schedule. The schedule includes a number of activities that are not properly linked to predecessor or successor activities. In addition, a significant number of predecessor activities converge or end at the same time. According to leading practices, this is of particular concern because as the number of predecessor activities converge, the likelihood that the successor activity will start on time quickly diminishes to zero.[33]

(2) The critical path—the longest continuous sequence of activities in a schedule that defines the earliest completion of activities—has three date constraints. Date constraints can prevent future activities from starting or finishing early. According to leading practices, when the critical path is free of date constraints, critical activities have zero float, and therefore any delay in the critical activity causes the same day-for-day delay in the program forecasted finish date.[34] Moreover, if the critical path is missing dependencies or has date constraints, lags, or activities without discrete end products, then it is not valid. Since this schedule has date constraints, the critical path is not valid. Unless the schedule can produce a valid critical path consistent with leading practices, the program office will not be able to provide reliable timeline estimates or identify when problems or changes may occur and their effects on downstream work.

(3) The schedule also shows positive total float values that likely do not represent the true amount of flexibility in the schedule. The average total float is more than 26 working months. A high amount of float indicates that schedule logic might be missing or invalid. Without accurate values of total float, the schedule cannot be used to identify activities that could be permitted to slip and thus

[33]GAO-16-89G.

[34]GAO-16-89G.

allow managers to release and reallocate resources to activities that require more resources to be completed on time. Incorrect float estimates may result in an inaccurate assessment of program completion dates. In addition, inaccurate values of total float falsely depict true program status, which could lead to decisions that may jeopardize the program.

Credible. We found that the development project schedule partially met the credible characteristic. A schedule is credible if, among other things, it (1) includes a robust schedule risk analysis to identify high-priority risks and schedule contingency needed to address risks, and (2) can be traced horizontally and vertically. These issues affect confidence in the results of the project's risk analysis.

(1) We found that the development schedule does include a schedule risk analysis to determine a confidence level for achieving the program schedule and how much additional time should be added to the schedule for contingency. However, we assessed the development project schedule to have only partially met leading practices for a credible estimate because even though Sikorsky completed a risk analysis, the risk assessment is not valid because the risk assessment must reflect reliable logic and clearly identify the critical path. Since we found the critical path to not be valid, this affects the confidence of the risk assessment.

(2) We identified issues with horizontal traceability of the development project schedule. For a schedule to be traceable horizontally and vertically, it must (1) reflect the sequencing of activities necessary for the project, and (2) lower-level schedules (that is, schedules that detail only a portion of the program but at a higher level of detail) should be able to be rolled up into the high-level program schedule. However, we found the project schedule had issues with the sequencing of all activities that could result in the schedule not correctly calculating how delays affect succeeding activities.

Improving the schedule so that it meets the well-constructed and credible characteristics of a reliable schedule, as defined in GAO's schedule guide, could give the Marine Corps, the program office, and Congress greater confidence in the project's schedule—including the likelihood of on-time completion—and improve decision-making over the remaining years of the program's development phase.

Program Already Facing Significant Procurement Cost Concerns and Added Concurrency Increases Risk

DCMA reported in September 2020 that the program could exceed its cost baseline agreed to at the initial production decision, thus making the program unaffordable. One element of a program's cost is unit recurring flyaway cost, which includes supplier material costs, scrap rates, direct labor hours, system engineering and program management hours, direct and indirect rates, and overhead rates. When a program's flyaway costs are higher than expected, funding does not align with initial estimates. Prior to the award of the low rate lot 4 helicopters, according to a program estimate, recurring flyaway costs were up to 30 percent higher than the program's objective of approximately $87 million (constant year 2017) per helicopter. The program recently awarded lot 4 and stated the flyaway cost for this lot is approximately $112.4 million (constant year 2017). According to the program office, they currently estimate the per aircraft flyaway costs for the entire procurement of 196 aircraft at $91.6 million (constant year 2017). If the program exceeds its cost targets, according to program officials, it will need to request additional funding, defer capabilities to the future, or cut quantities.

Sikorsky and the program office have agreed on a plan for additional, specific steps to reduce costs, though nothing has been implemented yet. The goal is to reduce helicopter costs, including supplier material costs/yield, scrap rates, labor costs, indirect rates, and overhead. However, even with these efforts, the program is at risk of increased costs due to the concurrency (overlap of testing and production) in the program. In our previous reviews of weapon systems, we found that while some concurrency is understandable, it can also result in performance shortfalls, unexpected cost increases, schedule delays, and test problems, and deny timely, critical information to policymakers.[35]

Increased concurrency in the CH-53K program has increased the program's cost risk. In 2011, we reported on the level of concurrency in

[35]GAO, *Missile Defense: Opportunity Exists to Strengthen Acquisitions by Reducing Concurrency*, GAO-12-486 (Washington, D.C.: Apr. 20, 2012); *Defense Acquisitions: Production and Fielding of Missile Defense Components Continue with Less Testing and Validation Than Planned*, GAO-09-338 (Washington, D.C.: Mar. 13, 2009); and *Best Practices: Capturing Design and Manufacturing Knowledge Early Improves Acquisition Outcomes*, GAO-02-701 (Washington, D.C.: July 15, 2002).

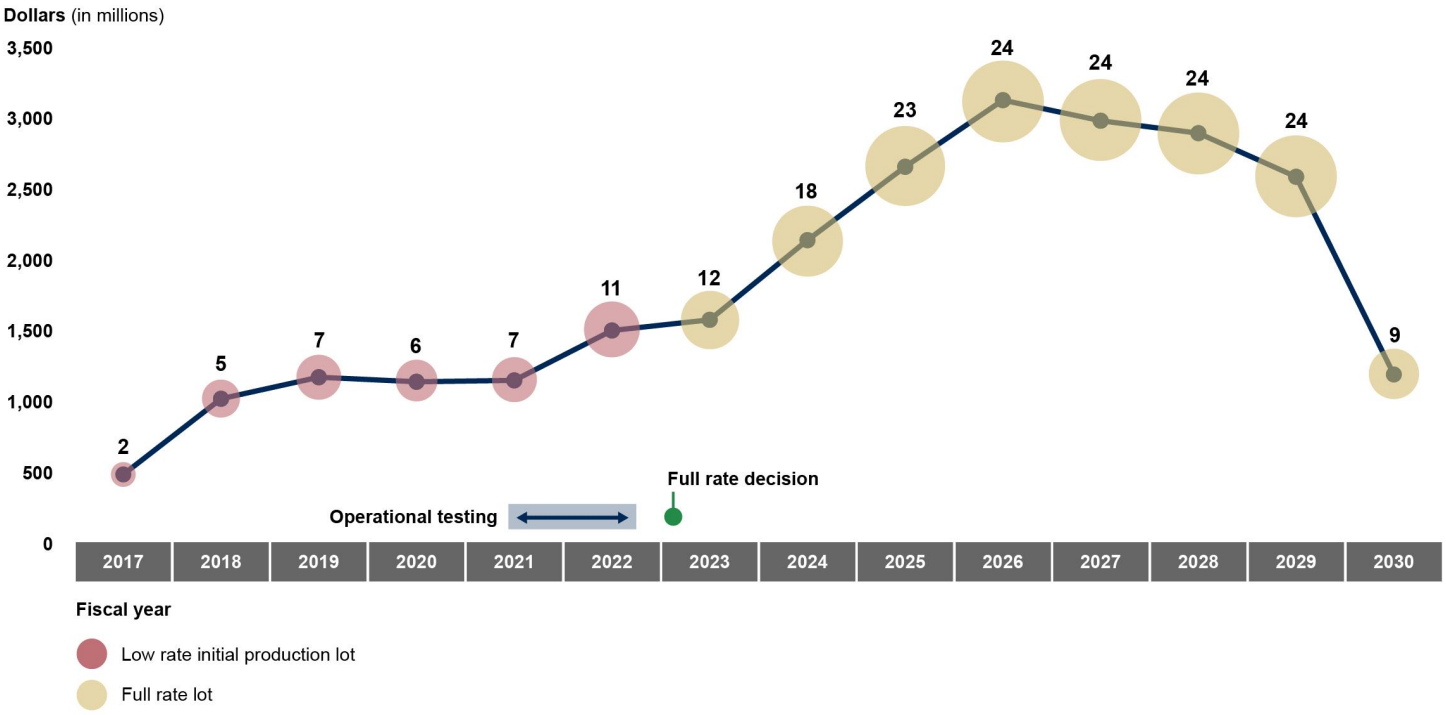
the CH-53K program schedule.[36] As we noted at that time, while some concurrency may be beneficial to efficiently transition from development into production, there is also risk in concurrency as changes in design and manufacturing processes could result in increased costs and delays in delivering capabilities to the warfighter. The program's experience in the subsequent years has demonstrated that risk.

Program officials acknowledge there is concurrency within the program and have tried to mitigate some of the risk. For example, they included a provision in the contracts for the low-rate production lots 2 and 3 that Sikorsky will be responsible for the first $5 million of recurring costs per aircraft attributable to new discoveries found during developmental efforts. In addition, program officials delayed the delivery of low-rate lot 1 so that the two helicopters in that buy could include some technical fixes.

Despite these mitigation efforts, concurrency risk remains, as reflected in the overlap of operational testing with planned production and costs of the CH-53K exhibited in figure 3.

[36]GAO-11-332.

Figure 3: Concurrency between Planned Production and Costs of the CH-53K



Source: GAO analysis of December 2019 Selected Acquisition Report and program office documents. | GAO-21-208

Data table for Figure 3: Concurrency between Planned Production and Costs of the CH-53K (in millions of dollars)

FY Year	Testing and Procurement Amount
2017	492.6
2018	1026.6
2019	1178.5
2020	1146.4
2021	1156.2
2022	1508.2
2023	1583.6
2024	2145.5
2025	2663.3
2026	3133.4
2027	2988.3
2028	2900.5
2029	2592.7
2030	1197.8

With the delays in completing operational testing, the program's concurrency and risk of rising costs due to it, has increased since we reported in 2011. The program will have been producing helicopters for nearly 6 years before the scheduled completion of operational testing, an increase of concurrency of nearly 3 years. As a result, the program now plans to procure a total of 38 helicopters in low-rate production over 6 years. By comparison, in 2011, the program planned to acquire a total of 29 helicopters in 3 years of low-rate production before completing initial operational test and evaluation. This raises the risk of cost increases because of the additional nine helicopters, increasing from 29 to 38, that may need retrofits.

Conclusions

The CH-53K is expected to perform a wide range of vital services that cannot be fully met by other Marine Corps aircraft, making the timely, successful completion of CH-53K development highly important. While the CH-53K program is nearing the end of development, much work remains to be done. The extent of the risk of the production line and supplier base will not be known until the program office completes planned work, now scheduled for 2022. Given the tightness of the time frames, it is concerning that the existing schedule for the program cannot be considered reliable, lacking key features that could make it a more useful tool for monitoring progress. Given the challenges ahead, a reliable schedule would provide DOD, the Congress, and other stakeholders better information to make key decisions.

Also, it remains important that program management continues to focus on resolving technical challenges that might affect the performance of the helicopter before producing more. Specifically, the extension of the schedule for completion of testing in the context of a planned increase in production of CH-53K helicopters raises the risk that costs will rise to pay for retrofitting aircraft produced before testing is completed. Increasing production beyond the current level of six per year—in the face of unresolved technical challenges and still-to-be completed testing—could prove costly and delay delivery of suitable aircraft to the warfighter. The completion of initial operational test and evaluation will reduce risk by providing decision makers, including Congress, with needed information on the resolution of the technical challenges before a decision is made to increase the annual production rate.

Recommendations for Executive Action

We are making the following two recommendations to the Secretary of the Navy.

The Secretary of the Navy should ensure that the project's integrated master schedule meets the credible and well-constructed characteristics of a reliable schedule, as defined in GAO's schedule guide. (Recommendation 1)

The Secretary of the Navy should not exceed the current level of annual procurement of six helicopters per year until initial operational test and evaluation is completed. (Recommendation 2)

Agency Comments and Our Evaluation

We provided a draft of this product to DOD for comment. DOD's comments are reproduced in appendix I. DOD also provided technical comments, which were incorporated as appropriate.

DOD did not concur with our recommendation that the CH-53K program's integrated master schedule should be revised to incorporate all GAO leading practices for project schedules. In its comments, DOD acknowledged that the integrated master schedule may not meet GAO's leading practices for project schedules, but maintained that the program's activities are properly sequenced and traceable. In addition, DOD stated that the schedule was reliable because it was developed jointly with government and industry experts and is maintained and reviewed routinely using standard industry practices. DOD raised concerns about the reprogramming of funds to develop a new schedule.[37]

We stand by our recommendation. The program's schedule only partially meets the attributes of a well-constructed and credible schedule based on leading practices. We acknowledge that the integrated master schedule substantially or fully meets five of the 10 best practices. We are not suggesting DOD reprogram funding to develop a new schedule; rather, our report recommends improving the existing schedule as part of ongoing schedule maintenance activities. Ensuring that all logic links are

[37]Reprogramming funding refers to shifting funds within an appropriation or fund account to use for purposes other than those contemplated at the time of the appropriation.

in place is routinely part of schedule maintenance that can, and should, take place regularly. By continually ensuring that activities are sequenced logically, program management would have greater confidence in the schedule's critical path and associated measures like total float and horizontal traceability, concerns we raised about the current schedule. Future schedule risk analysis results would benefit from these improvements as well. Improving the schedule so that it meets the well-constructed and credible characteristics of a reliable schedule would give the Marine Corps, the program office, and Congress greater confidence in the project's schedule, including the likelihood of on-time completion of the development contract, and improve decision-making over the remaining years of the program's development phase.

DOD also did not concur with our recommendation to limit the number of aircraft procured annually to six until the program completes initial operational test and evaluation. DOD stated that the reduction in the planned quantities in fiscal years 2021 and 2022 poses a greater risk to the affordability of the program than the risk posed by the remaining technical challenges. DOD also stated that there is no quantifiable data provided in this report that reasonably concludes that this recommendation will reduce the risk of the remaining technical challenges or potential concurrency issues. In addition, DOD stated that a major reduction in procurement would cause price increases, negatively affect the transition from the aging CH-53E fleet, and hurt the industrial base.

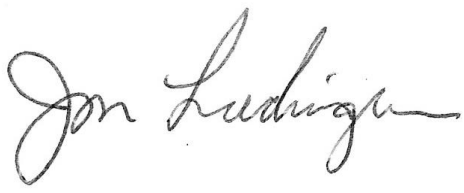
We continue to believe that our recommendation to hold production at current levels until testing can be completed is valid and reasonable, given the program's history of increasing concurrency and related costs. We maintain that it would be prudent to maintain the current level of production until the completion of the initial operational test and evaluation, when the program is able to more completely evaluate the sufficiency of the CH-53K. As previously stated in this report, while we have found in previous reviews of weapon systems that while some concurrency is understandable, high levels of concurrency can result in, among other things, performance shortfalls and increased costs and deny timely, critical information to policymakers. We recognize there are challenges with delaying the planned increase in production. However, the program and contractor delays in determining whether already-built CH-53Ks fully meet requirements have increased program concurrency and related costs to retrofit those aircraft. Maintaining the current production rate offers an opportunity to limit additional retrofit costs. We understand DOD's concerns that our report does not provide an estimate of the potential additional concurrency costs that may be avoided by

delaying the planned increase in production. But we lack, as does DOD, sufficient information about the range of potential additional deficiencies and other problems that could be identified while completing the planned testing. Uncertainty about the types of problems that can be uncovered during testing is the reason GAO leading practices indicate it can be helpful to limit concurrent development and testing.

Further, it is our view that deferring production of six helicopters until the completion of testing does not constitute the major reduction in procurement noted in DOD's response. The first deployment of the CH-53K would be met with helicopters that have already been procured, with deliveries of these helicopters planned through fiscal year 2024. We understand that the recommendation would have some effect on the schedule for producing all planned CH-53Ks. Our analysis of DOD's planned procurement rate indicates that the delay would be 18 months, at most. We appreciate that already-delayed production—more than 4 years—has left the Marine Corps in need of the CH-53K, but the deferred deliveries would better ensure that the CH-53Ks fully meet the needs of the Marine Corps and do not require additional, costly retrofits to address any issues that could emerge during final testing. Finally, it remains uncertain how the delayed quantities could impact the delivery of all needed CH-53K in light of the findings of the Force Design study, which recommended reducing the number of heavy lift squadrons from eight to five.

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

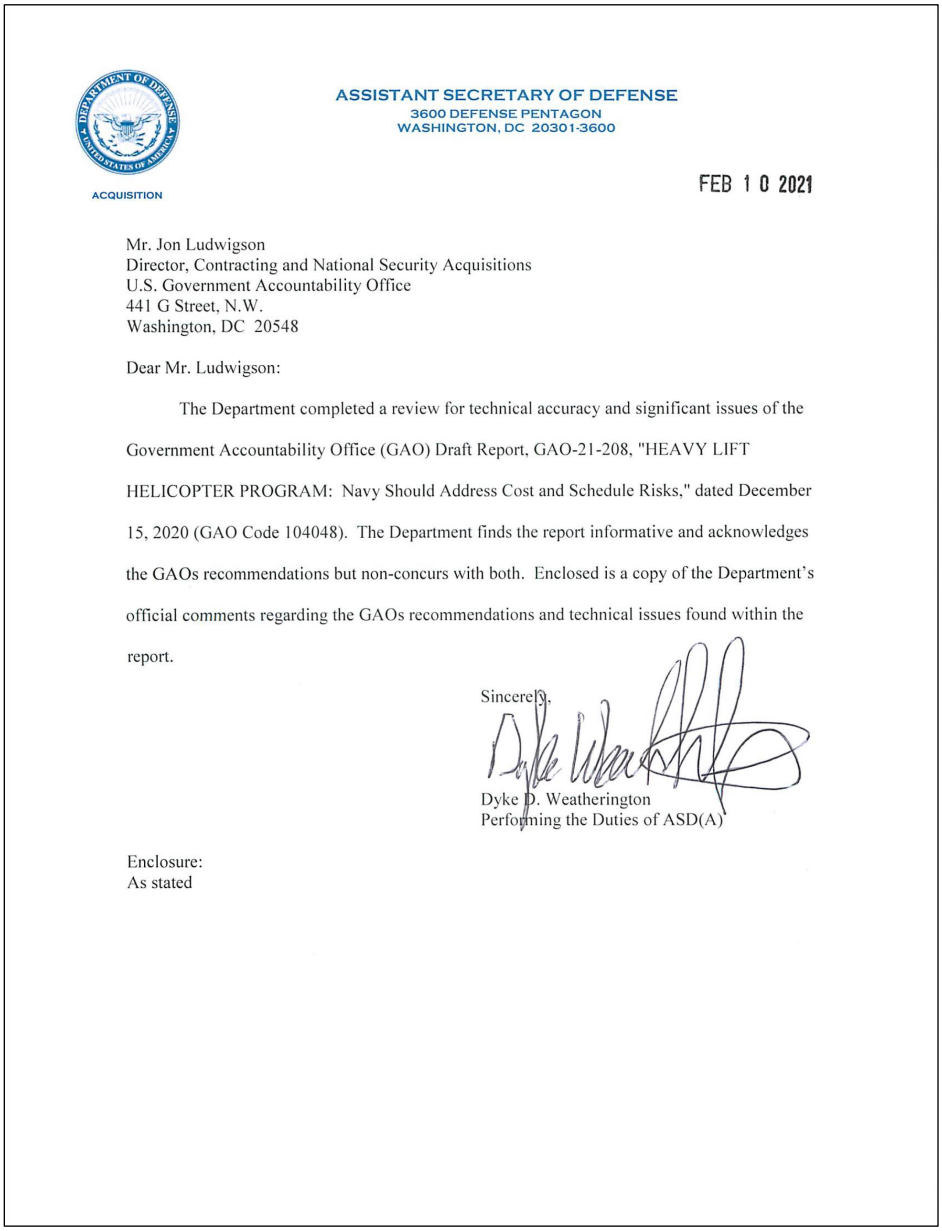
If you or your staff have any questions about this report, please contact me at (202) 512-4841 or ludwigsonj@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed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



Jon Ludwigson

Director, Contracting and National Security Acquisitions

Appendix I: Comments from the Department of Defense



ASSISTANT SECRETARY OF DEFENSE
3600 DEFENSE PENTAGON
WASHINGTON, DC 20301-3600

ACQUISITION

FEB 1 0 2021

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

Dear Mr. Ludwigson:

The Department completed a review for technical accuracy and significant issues of the Government Accountability Office (GAO) Draft Report, GAO-21-208, "HEAVY LIFT HELICOPTER PROGRAM: Navy Should Address Cost and Schedule Risks," dated December 15, 2020 (GAO Code 104048). The Department finds the report informative and acknowledges the GAOs recommendations but non-concurs with both. Enclosed is a copy of the Department's official comments regarding the GAOs recommendations and technical issues found within the report.

Sincerely,

Dyke D. Weatherington
Performing the Duties of ASD(A)

Enclosure:
As stated

GAO DRAFT REPORT DATED DECEMBER 15, 2020
GAO-21-208 (GAO CODE 104048)

"HEAVY LIFT HELICOPTER PROGRAM: NAVY SHOULD ADDRESS COST AND SCHEDULE RISKS"

DEPARTMENT OF DEFENSE COMMENTS
TO THE GAO RECOMMENDATIONS

RECOMMENDATION 1: The GAO recommends that The Secretary of the Navy should ensure the project's integrated master schedule meets the credible and well-constructed characteristics of a reliable schedule, as defined in GAO's schedule guide. (Recommendation 1)

DoD RESPONSE: Nonconcur. The Department does not concur with the recommendation to ensure that the CH-53K program's integrated master schedule (IMS) meets the characteristics of a reliable schedule as defined in GAO Schedule Assessment Guide: Best Practices for Project Schedules. The schedule was assessed as partially well-constructed and partially credible, and therefore unreliable.

The schedule was considered to be only partially well-constructed due to its sequencing of activities, date constraints within its critical path, and total float values. The CH-53K Program Office contends that during its June 2020 Over Target Baseline (OTB) Integrated Baseline Review (IBR), it was determined that all appropriate schedule interdependencies were accounted for, and discrete scope of work was logically and appropriately linked. Quantifiable back-up data were validated, and durations were reviewed for realism. At that time, the program team determined that there is moderate risk of duration growth. Further, the program team conducts critical/near-critical path, driving/near-driving path, and float analyses on a monthly basis to determine accuracy and realism. The program asserts that its schedule is well-constructed.

The schedule was rated only partially credible for horizontal traceability due to the above determination that its activities are not properly sequenced; and the program's schedule risk analysis (SRA) was deemed not valid due to the above assessment of the schedule's critical path. The schedule's logic interdependencies can be traced horizontally through the network schedule and also through task hierarchy. Each activity is also traceable to the program's Work Breakdown Structure (WBS) and Statement of Work (SOW). An SRA was conducted on the schedule prior to and after implementation of the OTB and indicated an acceptable level of risk for completion of all scope of work by the contractual deadline. The program affirms that its schedule is credible.

While the Department concurs that its IMS may not fully meet all criteria as defined in the referenced guide, it does not concur that the program schedule is not reliable. The program schedule was developed jointly with government and industry experts, is maintained and routinely reviewed using rigorous, standard industry practices, and has been an effective tool in managing the program's technical progress since its implementation in December 2018. The

Department does not intend to invest, nor require the Navy or Marine Corps to reprogram funds into development of a new schedule or modifications to the existing schedule construction.

RECOMMENDATION 2: The GAO recommends that the Secretary of the Defense should ensure The Secretary of the Navy should not exceed the current level of annual procurement of six helicopters per year until initial operational test and evaluation are completed. (Recommendation 2)

DoD RESPONSE: Nonconcur. The Department does not concur with the recommendation to limit the annual procurement to six helicopters per year until initial operational test and evaluation is completed. A reduction in planned FY2021 and FY2022 quantities poses greater risk to the viability and affordability of the production program than the risk posed by the remaining technical challenges. Additionally, there is no quantifiable data provided in the report that reasonably concludes that procuring six helicopters per year will reduce the risk of remaining technical challenges or potential concurrency issues.

The production ramp in the FY2021 President's Budget as shown in Table 1 supports the Initial Operating Capability and Full Operational Capability timeline directed by the Capability Production Document for the USMC CH-53K Program Version 1.1 dated 3 February 2020. Decreasing quantities as recommended will place substantial risk on that timeline.

Table 1: CH-53K Procurement quantity ramp, FY2021 President's Budget

	FY2021	FY2022	FY2023	FY2024	FY2025
CH-53K	7	11	12	18	23

Per the Acquisition Program Baseline dated 26 November 2019 and the program's current schedule, initial operational test and evaluation will complete in FY2022, however, this recommendation would not only affect FY2021 and FY2022. Reductions of one aircraft in FY2021 and five in FY2022 would require subsequent reductions in future years to reestablish a realistic, achievable production ramp rate. Program progress to date would be undermined by stalling the learning curve and a potential loss of key suppliers whose investments and strategies have been based on the budgeted profile. A major reduction in procurement would cause significant cost increases from Sikorsky and its suppliers as well as significant delays to transitioning the Fleet Marine Force from the aging CH-53E to the CH-53K.

The Marine Corps' optimized procurement ramp will achieve the following:

1. Support *CMC Force Design* efforts by providing a CH-53K with Full Operational Capability in 2029 per the *Capability Production Document* validated by the Joint Requirements Oversight Council in 2020.

2. Support a first deployment of CH-53K in 2024 and subsequent Global Force Management requirements in support of the Joint Force in 2024 and beyond.

3. Incrementally increase procurement quantities to full rate production in order to realize cost savings through reduction in supplier costs, cost reduction initiatives, and multi-year agreements.

If a change to the Approved Acquisition Objective (AAO) is made by the Commandant of the Marine Corps due to a reduction in Marine Corps CH-53 squadrons per CMC Force Design, the Marine Corps will adjust quantities per year (as required) to a level that meets operational requirements and maximizes affordability.

Text of Appendix I: Comments from the Department of Defense

Page 1

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Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

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

Staff Acknowledgments

In addition to the contact named above, Bruce H. Thomas (Assistant Director), Peter W. Anderson, Juana Collymore, Victoria Klepacz, Jean McSween, Sylvia Schatz, Jenny Shinn, Roxanna Sun, Alyssa Weir, and Chris Woika made major contributions to this report.

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