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CH-53K HEAVY-LIFT HELICOPTER PROGRAM ACQUISITION CASE HISTORY

by

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December 2020

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The purpose of this research is to analyze the acquisition process of the U.S. Marine Corps (USMC) CH-53K King Stallion heavy-lift helicopter. With the ability to carry 27,000 lbs over 110 nautical miles in hot temperatures and within the same shipboard logistic footprint as its predecessor, the CH-53K will be the backbone of the USMC's ship-to-shore aviation operations. However, numerous performance setbacks have incurred significant cost growth for the USMC and delayed the aircraft's deployment to 2023–2024, two decades after the program was initiated in 2003. This research examines the program, in the format of a case history, to better understand the decisions and scenarios that led to increased cost growth and delayed schedules. The case history is intended to educate readers on the numerous complex considerations found within any acquisition process, in the hopes of applying the lessons learned to future programs in order to provide the best solution for the warfighter.

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CH-53K HEAVY-LIFT HELICOPTER PROGRAM ACQUISITION CASE HISTORY

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ABSTRACT

The purpose of this research is to analyze the acquisition process of the U.S. Marine Corps (USMC) CH-53K King Stallion heavy-lift helicopter. With the ability to carry 27,000 lbs over 110 nautical miles in hot temperatures and within the same shipboard logistic footprint as its predecessor, the CH-53K will be the backbone of the USMC's ship-to-shore aviation operations. However, numerous performance setbacks have incurred significant cost growth for the USMC and delayed the aircraft's deployment to 2023–2024, two decades after the program was initiated in 2003. This research examines the program, in the format of a case history, to better understand the decisions and scenarios that led to increased cost growth and delayed schedules. The case history is intended to educate readers on the numerous complex considerations found within any acquisition process, in the hopes of applying the lessons learned to future programs in order to provide the best solution for the warfighter.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACAT	Acquisition Category
A_o	Operational Availability
AoA	Analysis of Alternatives
APB	Acquisition Program Baseline
BES	Budget Estimate Submission
CAPE	Cost Assessment and Program Evaluation
CASEVAC	Casualty Evacuation
CDD	Capability Development Document
CDR	Critical Design Review
CH-53E	Sikorsky's Super Stallion (predecessor to the CH-53K)
CH-53K	Sikorsky's King Stallion (newest model)
CJCS	Chairman of the Joint Chiefs of Staff
CPD	Capabilities Production Document
DAS	Defense Acquisition System
DOD	Department of Defense
DON	Department of the Navy
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, and Education
DOT&E	Director, Operational Test and Evaluation
DPG	Defense Planning Guidance
DRFPRD	Development Request for Proposal Release Decision
EDM	Engineering Development Model
FFP	Firm-Fixed Price
FRP	Full-Rate Production
FYDP	Future Year Defense Program
GAO	Government Accountability Office
GTV	Ground Test Vehicle
HMH	Marine Heavy Helicopter squadron
HMMWV	High Mobility Multipurpose Wheeled Vehicles
ICD	Initial Capabilities Document

IOC	Initial Operational Capability
IOT&E	Initial Operational Testing and Evaluation
JCIDS	Joint Capabilities Integration and Development System
JLTV	Joint Light Tactical Vehicle
JROC	Joint Requirements Oversight Council
KPP	Key Performance Parameter
LAV	Light Armored Vehicle
LFT&E	Live Fire Testing and Evaluation
LHD	Landing Helicopter Dock
LRIP	Low-Rate Initial Production
MDA	Milestone Decision Authority
MDD	Materiel Development Decision
MPF(F)	Maritime Pre-Positioning Force (Future)
MS	Milestone
MSA	Materiel Solution Analysis
NAVAIR	Naval Air Systems Command
OA	Operational Assessment
OT&E	Operational Testing and Evaluation
O&S	Operating and Support (Appropriation)
O&S	Operations and Support (Phase)
PDR	Preliminary Design Review
POM	Program Objective Memorandum
POR	Program of Record
PPBE	Planning, Programming, Budgeting, and Execution
P&D	Production and Development
RAND	Research and Development Corporation
RFP	Request for Proposal
SDD	System Development and Demonstration
SDTA	System Demonstration Test Articles
SECDEF	Secretary of Defense
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
USMC	United States Marine Corps

I. INTRODUCTION

With the average age of the CH-53E Super Stallion at a staggering 32.6 years old, the U.S. Marine Corps (USMC) is in critical need of a heavy-lift helicopter replacement (Reim, 2018). As modern weapon systems become more complex, many become heavier and require an aircraft with increased lift capacity for the USMC to remain mission capable. In 2000, the USMC announced plans to build such an aircraft while also budgeting to extend the service life of the current CH-53E to 2025 (Naval Technology, n.d.-a). The Heavy Lift Replacement Program, featuring what was later named the CH-53K King Stallion, was initiated in 2005 with an anticipated initial operational capability (IOC) in September 2015. Capable of lifting 27,000 lb (12,247 kg) for 110 nautical miles in high/hot environments and up to 36,000 lb (16,329 kg) in less extreme temperatures, the CH-53K can lift three times the load of its predecessor (U.S. Navy, 2019). Using its external cargo hook, the CH-53K can lift two high mobility multipurpose wheeled vehicles (HMMWV), two joint tactical vehicles (JLTV), or a light armored vehicle (LAV) while still carrying supplies internally as shown in Figure 1 (Marines, n.d.).

Figure 1. CH-53K King Stallion lifts a JLTV during testing demonstration in Patuxent River, MD. Source: Snow (2018).

Like the CH-53E, its mission sets will include assault transport of weapons, equipment, and Marines; recovery of downed aircraft or equipment; casualty evacuation; airborne assault support; and humanitarian assistance as shown in Figure 2 (Perrin, 2018). The CH-53K's increased capability compared to its predecessor, while still maintaining the same shipboard logistical footprint, makes it an unparalleled asset in the USMC aircraft arsenal. Unfortunately, repeated program delays—including poor performance testing results, budgetary constraints, and contractor challenges—pushed the warfighter's IOC to September 2021 with full operational capability delayed until 2023–2024.

Figure 2. CH-53E Super Stallion recovers downed Canadian CH-47 Chinook in Kandahar Province, Afghanistan. Source: James (2011).

Until early 2020, the CH-53K program was under heavy scrutiny by the Pentagon and Congress for its repeated delays, poor technical performance, and additional requests for more funding when the aircraft's numerous deficiencies had few foreseeable solutions. Considerations for alternatives, such as a modified CH-47F Chinook, a medium-lift helicopter originally built for the U.S. Army, were proposed as a replacement for the CH-53K, since its technical deficiencies were unlikely to be solved. Despite congressional pressures, Lieutenant General Steven Rudder, the deputy commandant for aviation, continued to advocate for the CH-53K and stated, “We have not found another platform that can accomplish everything we can off of a ship at the distances and weight that we’re asking it to do” (Harkins, 2019, para. 3).

Even after most of the CH-53K’s technical problems were solved in late 2019, the Pentagon still considered reducing the 200 CH-53K order and supplementing operational need with the modified CH-47 in order to reduce costs (Trail, 2020). From 1998 to 2003, the Department of Defense (DOD) armed forces attempted the Joint Shipboard Helicopter Integration Process (JSHIP) program in which they tried to develop a standard procedure to incorporate every Service’s rotary aircraft on board U.S. Naval ships (Trail, 2020). Ultimately, the initiative was canceled because, as Army Major General Geoffrey Lambert and Navy Lieutenant Commander Mark Huber explained,

> It is unreasonable to expect Army and Air Force helicopters to operate with the same ease on ships as their Navy and Marine Corps counterparts. … Unless Army and Air Force rotary-wing aircraft are designed with shipboard operations in mind—an expensive and unrealistic proposition—the same challenges will arise. (Trail, 2020, para. 6)

A. GOALS

The purpose of this research is to use the CH-53K program as a realistic example for students and experts alike to better understand the defense acquisition process and to improve decision-making for future acquisition programs. Specific goals of this research include

- explaining the importance of the CH-53K to the USMC,
- outlining the standard defense acquisition process, how the CH-53K program deviated from it, and whether these deviations improved or diminished the program’s outcome,
- developing a case history that outlines the CH-53K’s program of record (POR) to understand why the program office made certain decisions, and

- providing lessons learned and recommendations for future acquisition program handling and future research topics.

B. OVERVIEW

The following chapters describe the defense acquisition process and how it was used for the CH-53K program. After explicitly outlining the steps of the acquisition process and the POR for the CH-53K, the paper continues with a literature review of all official reports published on the program. This includes governmental reports, publications from third-party entities, and articles from news and media sources, all used to describe how the CH-53K will integrate into the fleet and the benefits the CH-53K will provide. The focus of this research is a case history, designed to analyze the critical decisions made throughout the CH-53K's POR and understand the influences behind those decisions. Lastly, this effort concludes with lessons learned and recommendations for future research.

II. BACKGROUND

The following chapter is divided into two parts. The first part outlines how the defense acquisition process operates in relationship to warfighter requirements and budget processes as well as all the major milestones and decision points within the defense acquisition system (DAS) as described in the DoDI 5000.02T, *Operation of the Defense Acquisition System*, updated January 23, 2020 (Department of Defense [DOD], 2020b). According to DoDI 5000.02, *Operation of the Adaptive Acquisition Framework* (AAF), effective as of January 23, 2020, the AAF is used to support the National Defense Strategy by delivering effective, suitable, survivable, sustainable, and affordable solutions to the warfighter through the DAS (Department of Defense [DOD], 2020a). Although adaptable to a specific program, the AAF is a general acquisition strategy (see Figure 3) that all acquisition efforts and major defense acquisition programs (MDAPs) follow to develop new technologies for the warfighter.

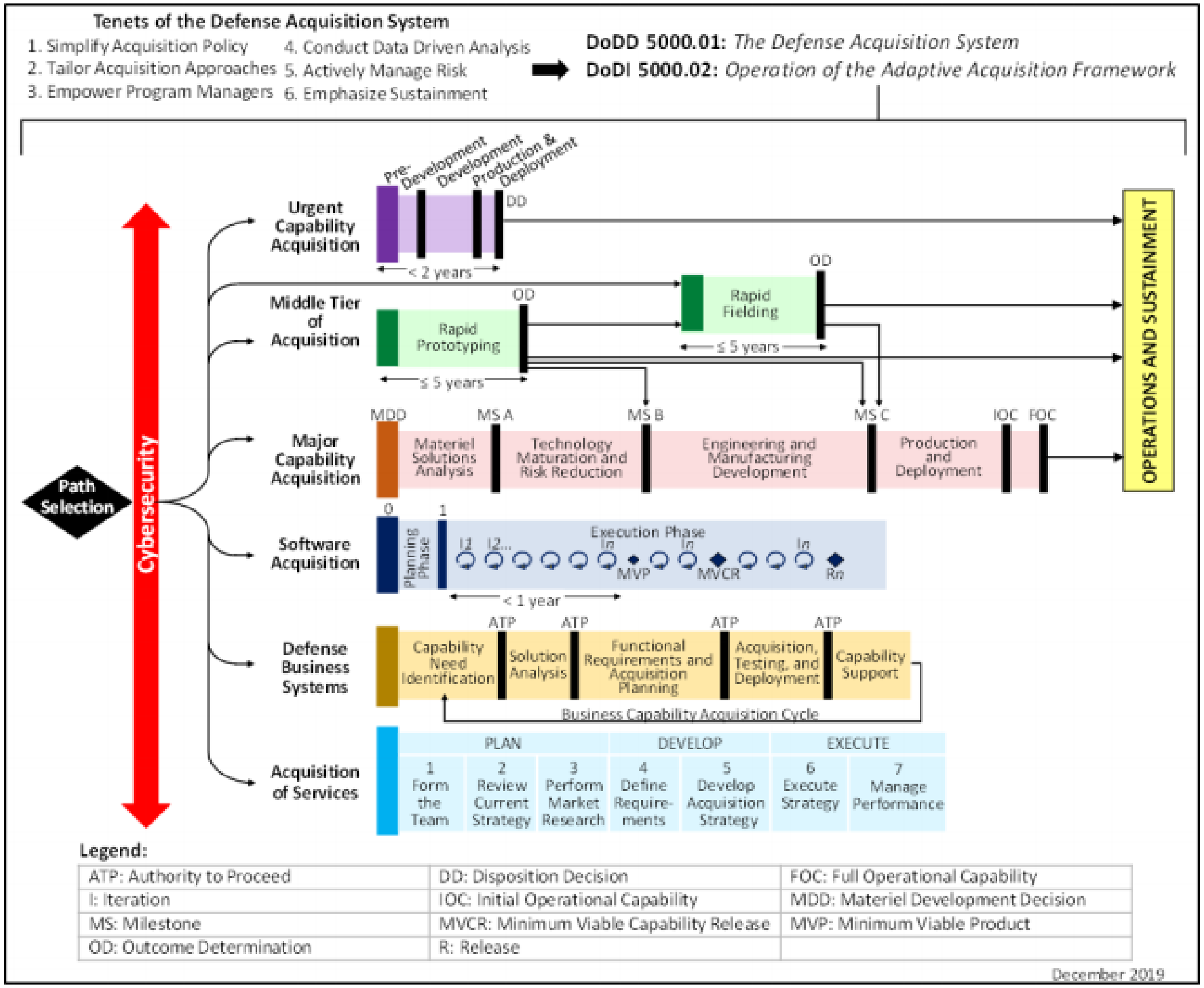

Figure 3. Adaptive Acquisition Framework. Source: DOD (2020a).

The second part of this chapter provides a history of the CH-53 platform since its first use in the Vietnam era and a description of the new CH-53K model's mission, capabilities, and operational deployment.

A. PART I: THE "BIG A" ACQUISITION PROCESS

Defense acquisition programs are organized into different categories based on their purpose, cost threshold, and decision authority. Programs are identified as MDAPs, Major Automated Information Systems (MAIS), or Major Systems and can be designated by acquisition categories (ACAT) I through III depending on cost and/or importance (DOD, 2020b). MDAPs that are estimated to exceed more than $480 million (constant year [CY] 2014 dollars) for research, development, test, and evaluation (RDT&E) or $2.79 billion (CY2014 dollars) are categorized as ACAT 1 programs (DOD, 2020b). The CH-53K King Stallion heavy-lift helicopter is an ACAT 1 program because it exceeds the cost criteria. ACAT II cost thresholds are $185 million (CY2014) for RDT&E or $835 million (CY2014) for procurement. ACAT III is any program that does not meet ACAT II criteria or above (DOD, 2020b). For all ACAT programs, the Milestone Decision Authority (MDA) reserves the right to designate a program as a higher level ACAT program because of the program's special interest, regardless of the cost criteria (DOD, 2020b).

Regardless of ACAT designation, all defense acquisition programs are subject to achieving identified capability requirements, through the DAS, within budgetary constraints (DOD, 2020b). This relationship is known as the "Big A" acquisition process. It is used by the federal government to obtain new or maintain old resources or services for the DOD. Identifying the technological requirements that the military needs, formulating a budget, and acquiring the technology is formally known as the relationship between the Joint Capabilities Integration and Development System (JCIDS); the Planning, Programming, Budgeting, and Execution (PPBE), and the DAS, respectively (see Figure 4; DOD, 2020b).

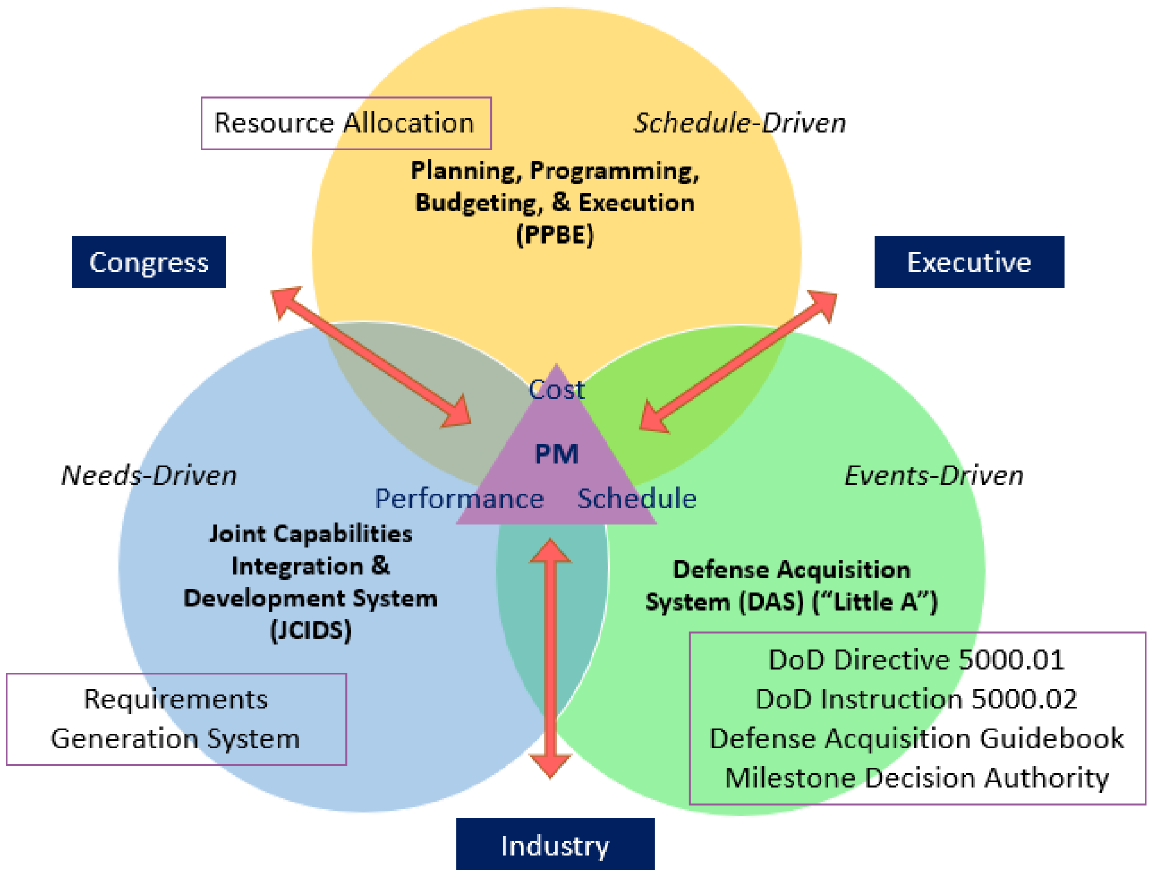

Figure 4. The "Big A" Acquisition Process. Source: Mortlock (2017).

- **Joint Capabilities Integration and Development System (JCIDS):** Identifies and validates warfighting requirements for the system and is a needs-driven process, meaning JCIDS is used when warfighters encounter a threat or capability gap that requires a solution (Mortlock, 2017).

- **Planning, Programming, Budgeting, and Execution (PPBE):** Focuses on planning and allocating financial resources according to the approved fiscal year budget. PPBE is a schedule-driven process because the DOD budget is approved by Congress annually and appropriations plan their expenditures annually (Mortlock, 2017).

- **Defense Acquisition System (DAS):** The management process that provides the system to the warfighter (also known as the "Little A"

Acquisition Process). The DAS is an event-driven process because developing a new technology requires the system to achieve the test and evaluation goals to meet the warfighter requirements validated in the JCIDS process (Mortlock, 2017).

The overlapping relationship between the JCIDS, PPBE, and DAS processes provides checks and balances within the "Big A" acquisition process. Although the goal is to provide warfighters with everything they need when they need it, realistic constraints like a limited budget and technology development are factors the "Big A" acquisition process considers to fulfill warfighter needs. As with any checks and balances systems, friction between each of the processes can occur, especially when each are driven by a different motivation, i.e., needs, schedule, or events.

1. Joint Capabilities Integration and Development (JCIDS)

The main guidance for the JCIDS process is Instruction 5123.01H, *Charter of the JROC and Implementation of the JCIDS*, dated August 31, 2018 (Joint Chiefs of Staff [JCS], 2018). The Joint Requirements Oversight Council (JROC) is a statutory council to the Chairman of the Joint Chiefs of Staff (CJCS) and, in accordance with 10 U.S.C. § 181, they are responsible for assessing, identifying, approving, and prioritizing joint capability gaps to meet the obligations in the National Defense Strategy using the JCIDS process (JCS, 2018). The JROC also supports the CJCS with developing the secretary of defense's (SECDEF) Defense Planning Guidance (DPG; JCS, 2018). By identifying, assessing, and prioritizing capability gaps in the operational environment, the JCIDS process can determine what kind of solution is needed to address the gap (Rausch, n.d.).

The DOTMLPF-P acronym refers to various approaches to find a solution for capability gaps. DOTMLPF-P stands for *doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy*. An operational capability gap could be satisfied by a change in any of these categories (Joint Chiefs of Staff [JCS], 2016). DOTMLPF-P categories are usually designated into materiel and non-materiel solutions. The JCIDS process resides within the materiel section of DOTMLPF-P and is only used when all non-materiel components have been considered and cannot provide a solution for the capability gap the warfighter is experiencing (JCS, 2016). Each component of DOTMLPF-P is described in more detail below.

- **Doctrine**: U.S. military forces are led by joint doctrine that address the fundamental principles in the way these forces fight for the objective, whether within a single service or within joint operations (JCS, 2016). Senior leaders will consider if there are better or more modern methods to maneuver and combine resources or update policies, laws, and treaties to address this operational gap (JCS, 2016).

- **Organization**: Joint concepts are built upon organizational structures that, if changed, could address the capability gap experienced by the warfighter (JCS, 2016). The main question considered is if the unit, service, joint services, etc., has the organizational structure (i.e., personnel or funding) to execute the appropriate warfighting capability (JCS, 2016).

- **Training**: Based off the joint doctrine, joint training is required to prepare forces for military operations and this component of DOTMLPF-P analyzes various training pipelines or exercises for potential solutions to capability gaps (JCS, 2016). In other words, could the gap be fulfilled with a modification to tactics, techniques, or training procedures (JCS, 2016)?

- **Materiel**: After all other DOTMLPF-P categories have been considered, the JCIDS process evaluates warfighter requirements to determine if the gap can be fulfilled with potentially a new system (JCS, 2016). Oftentimes, a materiel solution is only considered if the capability gap poses an unacceptable level of risk that requires a new system so warfighters can achieve the mission (JCS, 2016).

- **Leadership and Education**: This DOTMLPF-P component includes curriculums such as Joint Professional Military Education (JPME), Pinnacle and Capstone courses for general officers and flag officers, and the Keystone course for senior non-commissioned officers to prepare leaders to think critically and support sound judgement in all environments (JCS, 2016). With leadership and education, military forces can think critically and attempt to fill capability gaps with available resources before proposing new acquisition programs that are costly and take time to develop (JCS, 2016).

- **Personnel**: All operations require personnel, both military and civilian, with the appropriate skillsets to accomplish the mission (JCS, 2016). This component considers if the capability gap is caused by a lack of appropriately trained personnel in the proper positions to meet military objectives (JCS, 2016).

- **Facilities**: Essential to supporting military operations, command installations and industrial buildings are examined to ensure the appropriate infrastructure is in place to deploy, receive, stage, move, integrate, and sustain military operations (JCS, 2016).

- **Policy**: DOD, federal, or international policies that direct, task, prescribe, and guide the DOD in executing their mission for national security may influence how to approach solutions for capability gaps (JCS, 2016). This DOTMLPF-P component considers the intent of policies to certify that current and future solutions comply with their requirements (JCS, 2016)

When the Services, combatant commands, agencies, or the Joint Chiefs of Staff (JCS) identify an operational gap, they conduct a capabilities-based assessment that analyzes possible risk areas and shortfalls associated with the gap (Rausch, n.d.). They present a capability document—either an initial capabilities document (ICD) for a materiel solution or a DOTMLPF-P change recommendation for a non-materiel solution—to the JROC to initiate the JCIDS process (Rausch, n.d.). If the JROC approves the ICD, then a capability development document (CDD) for a materiel is developed, which is referenced and updated throughout the entire DAS (JCS, 2016). The CDD validates the key performance parameters (KPPs), which are the core technical objectives a program must achieve. The JROC will consider the risks associated with cost, schedule, and technological maturity for achieving the given KPPs before approving the CDD (JCS, 2018). The JROC validated CDD is required for a program of record to enter Milestone B (MS B) and release the development Request for Proposal (RFP) to potential contract bidders (JCS, 2018). A CDD Update, formerly called the Capability Production Document (CPD), is a follow-on JROC validation that is required for a program to enter Milestone C (MS C) and initiate Low Rate Initial Production (LRIP; JCS, 2018).

2. Planning, Programming, Budgeting, and Execution

The main guidance for the PPBE process is DOD Directive 7045.14, *The Planning, Programming, Budgeting, and Execution (PPBE) Process*, dated August 29, 2017 (Department of Defense [DOD], 2017). Within the AAF, PPBE process is responsible for the funding, financial management, and resource allocation of current and planned acquisition programs throughout every phase of the program's life cycle (DOD, 2017). Overall, the goals of PPBE is to support the DOD with the resources they need to execute the National Defense Strategy while considering fiscal constraints (DOD, 2017). The Quadrennial Defense Review (QDR), force development guidance, program guidance, and budget guidance steer the PPBE process to form budgets and programs annually and allocate funds quadrennially (DOD, 2017). The components of PPBE is described in further detail below.

a. Planning

To maintain the National Defense Strategy and support U.S. foreign policy, the planning phase tracks the priorities, affordability, risks, suitability, feasibility, and effectiveness of DOD resources (DOD, 2017). Led by the undersecretary of defense, the planning phase also analyzes the National Security Strategy and the National Military Strategy to align the Defense Planning Guidance with the goals of the administration (McGarry, 2020). The DPG considers potential threats, force organization, and readiness to guide the services as they develop their program objective memorandums (POMs; McGarry, 2020).

b. Programming

The programming phase is where the DOD services develop their POMs that annotate their proposed resource requirements (DOD, 2017). The CJCS will review the POMs and conduct risk assessments on the proposed capabilities and the ability to fund them (DOD, 2017). The Future Years Defense Program (FYDP) is updated after these risk assessments and the SECDEF can instruct the services to adjust their program objectives based off the FYDP (McGarry, 2020).

c. Budgeting

The DOD services will then develop a Budget Estimate Submission (BES) which is a proposed detailed budget of the program for the first year of the FYDP (DOD, 2017; McGarry, 2020). Resource requests are deconflicted among the services by the comptrollers, and then the SECDEF directs the services to update their budgets (McGarry, 2020). The updated BESs are then routed through the Office of Management and Budget and are included in the president's annual budget request to Congress (McGarry, 2020).

d. Execution

In the execution phase, plans developed in the planning, programming, and budgeting phases are carried out by allocating the budgeted funds to the services (DOD, 2017). Program results are also reviewed in this phase by comparing a program's actual performance with its planned performance, both financially and in terms of meeting warfighter needs (DOD, 2017).

3. Defense Acquisition System

Outlined in the AAF are several variations of the DAS that can be used to develop a program depending on program type and urgency (DOD, 2020a). This research will focus on the most traditional DAS path since the CH-53K program followed this path. In Figure 3, this traditional pathway is summarized in the third path labeled "Major Capability Acquisition" (DOD, 2020a). The major capability acquisition pathway is used to support

MDAPs and other complex acquisitions because it follows an analyze, design, develop, integrate, test, evaluate, produce, and support approach which is common for most defense acquisitions (DOD, 2020a). The other pathways annotated in Figure 3 are modified versions of the MDAPs path and are relevant for specific programs, i.e., software, services, rapid acquisitions, etc. (DOD, 2020a).

The main guidance for the DAS is DOD Instruction 5000.02, *Operation of the Adaptive Acquisition Framework*, dated January 23, 2020 (DOD, 2020a). The traditional DAS within the AAF consists of five phases that encompass the entire life cycle of the system (see Figure 5). Those phases are Materiel Solution Analysis (MSA), Technology Maturation and Risk Reduction (TMRR), Engineering Development and Manufacturing (EMD), Production and Development (P&D), and Operations and Support (O&S; DOD, 2020b). Incorporated within those phases are seven major decision points that determine whether the system should proceed to the next step, remain in its current step for further development, or be discontinued. Those decision points, also outlined in Figure 5, are Materiel Development Decision (MDD), Milestone A (MS A), CDD Validation, Development Request for Proposal Release Decision (DRFPRD), Milestone B (MS B), Milestone C (MS C), and the Full Rate Production (FRP) Decision (DOD, 2020b). They are described in more detail below.

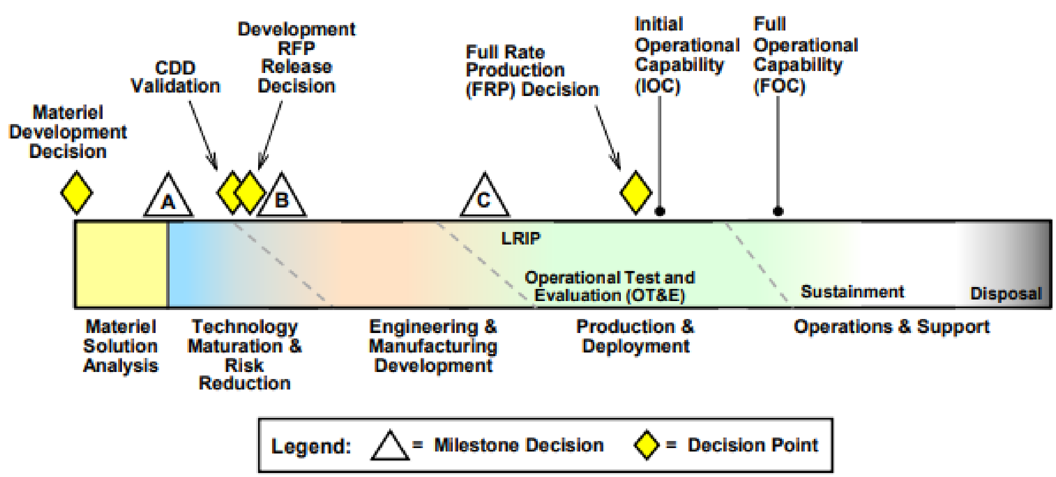

Figure 5. Major Milestones and Decision Points Outlined in the Adaptive Acquisition Framework of the Defense Acquisition System. Source: DOD (2020b).

a. Materiel Development Decision

The JROC validated ICD from the JCIDS is one of two components for the MDD (DOD, 2020b). The other component is an Analysis of Alternatives (AoA) Study Guidance and Study Plan which will guide the AoA in the MSA phase (DOD, 2020b). With these two documents, the MDA determines at what milestone a particular initiative should enter in the AAF based on urgency, resources, and technological maturity (DOD, 2020b). In this case, *initiative* is used to delineate from the term *program* because acquisition programs are not established with statutory requirements until MS B or MS C (DOD, 2020b). The MDA will also determine the lead DOD Component for the initiative (DOD, 2020b).

b. Materiel Solution Analysis Phase

The AoA Study Guidance and Study Plan that was completed for the MDD is executed in the MSA phase (DOD, 2020b). The AoA considers the trade space between cost, schedule, performance, risk, suitability, and effectiveness of viable solutions that could fulfill the capability gap (DOD, 2020b). This phase is designed to conduct the AoA by converting JROC validated capability gaps into system requirements (DOD, 2020b). These requirements are written as KPPs and key system attributes (KSAs), which further detail quantifiable performance measures the system should achieve by the time it is fully developed (DOD, 2020b). Combined with the ICD, KPPs and KSAs create a draft CDD that is repeatedly referenced and updated throughout the acquisition process (JCS, 2016). During the MSA, the program manager (PM) is selected and a program office is established to lead the system through the next steps of the acquisition cycle, either ultimately to the warfighter or to cancellation (DOD, 2020b).

c. Milestone A

At the MS A decision point, entry into the TMRR phase is approved by the MDA and finalized development RFPs are published to explain technical and performance requirements to potential contractors who will bid for the contract (DOD, 2020b). This RFP is strictly for the technology development and risk reduction efforts; usually, other RFPs are issued to support EMD phases or P&D phases further in the DAS (DOD, 2020b).

d. *Technology Maturation and Risk Reduction Phase*

TMRR is used to reduce any risks associated with the development of a new program, such as technology, engineering, integration, and life-cycle costs, before large-scale production (DOD, 2020b). Prototypes may be developed, tested, and refined to create a sufficient design solution that achieves the requirements and considers the trade space between cost and capability (DOD, 2020b). The results of the prototype or technology demonstrations are outlined in a preliminary design review (PDR), which validates that the proposed system design is ready for engineering and manufacturing development (DOD, 2020b).

e. *Capability Development Document Validation*

Within the TMRR phase, the draft CDD developed during the MSA phase is updated and validated when the program's requirements are determined technically achievable, affordable, and testable (DOD, 2020b). The CDD describes the system's KPPs and KSAs to provide guidance for the upcoming DRFPRD and PDR before MS B (DOD, 2020).

f. *Development Request for Proposal Release Decision*

The DRFPRD is a critical decision that determines whether a system's capability requirements, affordability, and executability are feasible (DOD, 2020b). The DRFPRD authorizes RFPs for the EMD phase, which the remaining contractors will bid on for the EMD contract (DOD, 2020b).

g. *Milestone B*

MS B initiates the EMD phase and authorizes the awarding of an EMD contract (DOD, 2020b). This decision point is a final demonstration that program risks, such as technology, engineering, integration, manufacturing, sustainment, and affordability, have been mitigated (DOD, 2020b). An approved MS B decision officially initiates the program with an Acquisition Program Baseline and commits fiscal resources to the system (DOD, 2020b). An MDA approved APB is the main document that tracks the cost, schedule, and performance of the program (DOD, 2020b).

h. *Engineering and Manufacturing Development Phase*

The EMD phase is when the system is developed, built, and tested to ensure all KPPs and other requirements are attained to support production and deployment of the system (DOD, 2020b). This includes all hardware and software designs and may require several rounds of testing to solidify a stable design (DOD, 2020b). EMD can include both developmental testing and evaluation (DT&E) and operational testing and evaluation (OT&E; DOD, 2020b). DT&E focuses on the system's compliance to its technical specifications, KPPs, and requirements (DOD, 2020b). OT&E concentrates on the system's effectiveness, suitability, and survivability for the warfighter's identified capability gap (DOD, 2020b). By the end of the EMD phase, the program should have a stable design, meet the requirements outlined in the CDD, and have demonstrated consistent manufacturing processes for the upcoming production phase (DOD, 2020b).

i. *Milestone C*

The purpose of the Milestone C (MS C) decision is to demonstrate that the program's technical design is stable and will meet all operational requirements, manufacturing risks are mitigated, and software development is deemed mature (DOD, 2020b). A validated CDD Update is required at the MS C decision to guide the program through the production phase (DOD, 2020b).

j. Production and Deployment Phase

The P&D phase is intended to produce and deliver a usable system to the warfighter (DOD, 2020b). The system will undergo several events in this phase, starting with low rate initial production (LRIP)—where a small number of systems are produced and deployed to conduct further testing (DOD, 2020b). Various types of OT&E, including initial operational test and evaluation (IOT&E) and live-fire test and evaluation (LFT&E), are conducted with the LRIP systems to determine the system's performance capability in an operational capacity (DOD, 2020b). During this phase, the MDA will evaluate the system to determine readiness for full rate production (DOD, 2020b).

k. Full Rate Production Decision Point (Full Deployment Decision Point for IT Systems)

After analyzing results from OT&E, initial manufacturing, and operational performance with the LRIP articles, the MDA will decide whether the program acceptably meets its system requirements to proceed to FRP (DOD, 2020b). The FRP decision leads to IOC and eventually Full Operational Capability (FOC; DOD, 2020b).

l. Operations and Support Phase

The O&S phase is when the system is fully deployed to the warfighter and must be maintained and sustained throughout its life cycle (DOD, 2020b). This is most expensive phase throughout the program's life cycle (see Figure 6). The O&S phase concludes with the proper disposal of the system at the end of its useful life (DOD, 2020b).

Costs are not distributed evenly throughout a program's life cycle. Figure 6 depicts the expected cost profile over the course of program's life cycle in relation to the five phases in the DAS (OSD, 2014). Funding for each of these phases does not all come from the same appropriation throughout the acquisition life cycle. Although there are numerous appropriations for specific needs, the acquisition process operates and reports its cost estimations in three main appropriations: RDT&E, procurement, and operating and support (O&S). RDT&E funds are used for the program's testing and development activities (i.e., during the early development phases and any testing evaluations conducted throughout the acquisition process; Office of the Secretary of Defense [OSD], 2014). Procurement funds are used when the program is approved for the MS C decision and can commence production, either for LRIP or FRP (OSD, 2014). O&S funds are consequently used during the operations and support phase (OSD, 2014). Other appropriations that could be utilized during the acquisition life cycle are operations and maintenance (O&M), military construction (MILCON), and military personnel (MILPERS). O&M is used in relation to production and deployment activities (OSD, 2014).

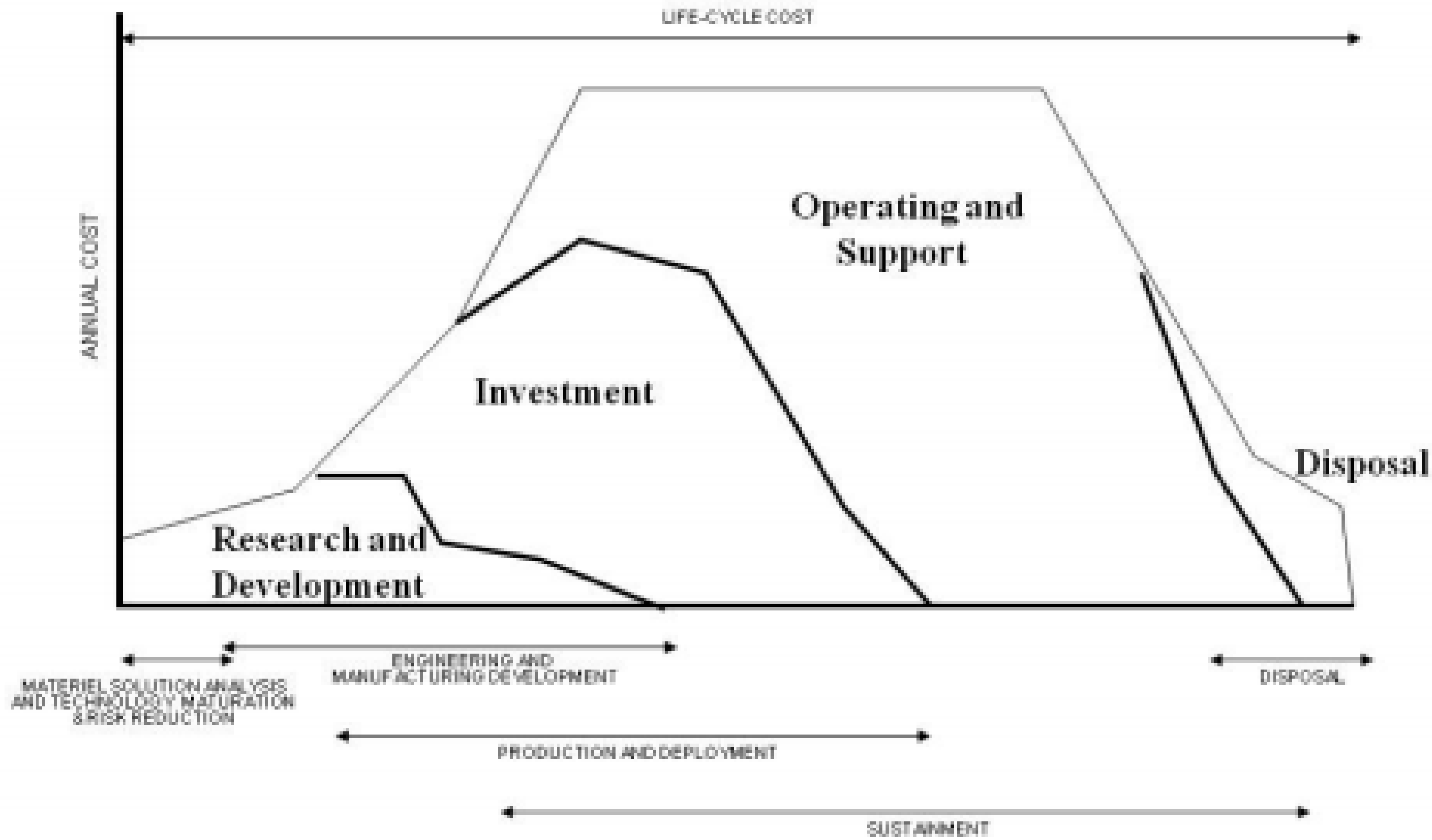

Figure 6. Program Life Cycle Cost Profile in Relation to the DAS phases. Source: Office of the Secretary of Defense (2014).

B. PART II: THE CH-53K HEAVY-LIFT HELICOPTER PROGRAM

The following sections of this chapter provide a brief background on the CH-53K by explaining where it came from and where it is headed. Once completed, the CH-53K will be the most powerful heavy-lift helicopter in the world (Snow, 2019). Improved maintainability and reliability will significantly decrease operating costs and increase operational effectiveness (DOD, 2018). With the CH-53K in their arsenal, the USMC will be able to meet their heavy-lift requirements in extreme temperatures and environmental conditions, so they can continue their role as a rapidly deployable, first-to-the-fight force.

1. History of the CH-53

The Heavy Helicopter Experimental (HHX) program was initiated in 1962 by the U.S. Navy's Bureau of Naval Weapons in the hopes of designing an aircraft capable of assault transport, personnel transport, aircraft recovery, and casualty evacuations (Fort Worth Aviation Museum, 2015). Sikorsky won the contract, and within 4.5 years, the first CH-53A arrived in Vietnam (see Figure 7; Fort Worth Aviation Museum, 2015).

Figure 7. CH-53A/D *Sea Stallion* in Vietnam. Source: Naval History and Heritage Command (2014).

Throughout the 1970s and 1980s, various versions of the CH-53 were produced for the different services and for several countries. The Air Force favored the HH-53B for its more powerful engines and digital electronics and countermeasures capability, which were useful during combat search and rescue missions (Schuster, 2012). The USMC quickly upgraded to the CH-53D in 1970, which incorporated the HH-53B's engines without the additional digital electronics and countermeasures equipment to allow for a heavier lifting capacity (Schuster, 2012). Israel acquired the CH-53D, and Germany introduced the CH-53G—a CH-53D variant—in the early 1970s, which are expected to last until the 2030s (Freedberg & Egozi, 2019; Lockheed Martin, n.d.). When the CH-53K began, both countries were interested in acquiring a new heavy-lift helicopter. Sikorsky's CH-53K and Boeing's CH-47F are suitable candidates to fulfill their needs.

The CH-53E (see Figure 8) is the USMC's current heavy-lift helicopter that has been in service since 1980. Its design incorporated a third engine, which further increased the aircraft's lift capacity (Fort Worth Aviation Museum, 2015). As the aircraft aged, the USMC initiated the Heavy Lift Replacement program in 2003, which eventually developed into the CH-53K program. In 2007, the USMC started replacing their older CH-53D aircraft with the MV-22 Osprey, which accomplishes the same or similar missions with its tiltrotor design (Fort Worth Aviation Museum, 2015). As the CH-53K begins to reach the squadrons, the USMC will need to reassess their implementation of both the CH-53K and the MV-22, since they have similar mission sets (see section titled RAND in Chapter III).

Figure 8. CH-53E *Super Stallion* lands on the flight deck of U.S.S. *Bataan* (LHD 5) Source: Eckstein (2019a).

2. CH-53K Mission and Capability

The USMC initiated the CH-53K Heavy Lift Replacement program to address their critical shortage of heavy-lift aircraft as the CH-53E aged and as modern weapon systems became increasingly heavier (Government Accountability Office [GAO], 2011b). The goal for the CH-53K is to exceed the CH-53E's performance in lift and range capabilities, commonality, reliability, maintainability, interoperability, ship integration, survivability, and force protection (Perrin, 2018).

The director, Operational Test and Evaluation (DOT&E), listed the following mission capabilities for the CH-53K:

- heavy-lift missions, including assault transport of weapons, equipment, supplies, and troops

- support for forward arming and refueling points and rapid ground refueling

- assault support in evacuation and maritime special operations

- casualty evacuation
- recovery of downed aircraft, equipment, and personnel
- airborne control for assault support (Behler, 2019)

With its triple-hook external cargo system, the CH-53K can either carry heavy ground equipment—such as the HMMWV, LAV, and JLTV—or three independent supply loads that can be easily delivered to three separate locations without reconfiguration (Marines, n.d.; United States Navy, 2019). Internal cargo loading is also compatible with fixed-wing configurations, so supply pallets offloading from fixed-wing aircraft and onto the CH-53K require no reconfiguration (Marines, n.d.).

Compared to its predecessor, the CH-53K is slightly larger, but has the same shipboard footprint and a reduced logistical footprint to make the aircraft easier to maintain (see Figure 9). The slightly larger cabin of the CH-53K allows for not only larger supply pallets but also an internally loaded HMMWV to be transported by the aircraft which provides additional flexibility in military operations (U.S. Navy, n.d.). Figure 9 highlights other technological advances found in the CH-53K, such as the modern glass cockpit, fly-by-wire controls, and composite main rotor blades designed to provided more lift than the CH-53E (U.S. Marine Corps Aviation, 2019). Additionally, the CH-53K's engines are built with 63% fewer parts but provide 57% more horsepower than the CH-53E to provide more lift and simplify maintenance procedures (U.S. Marine Corps Aviation, 2019). A more detailed comparison of the CH-53K's capabilities regarding the CH-53E is provided in Figure 10.

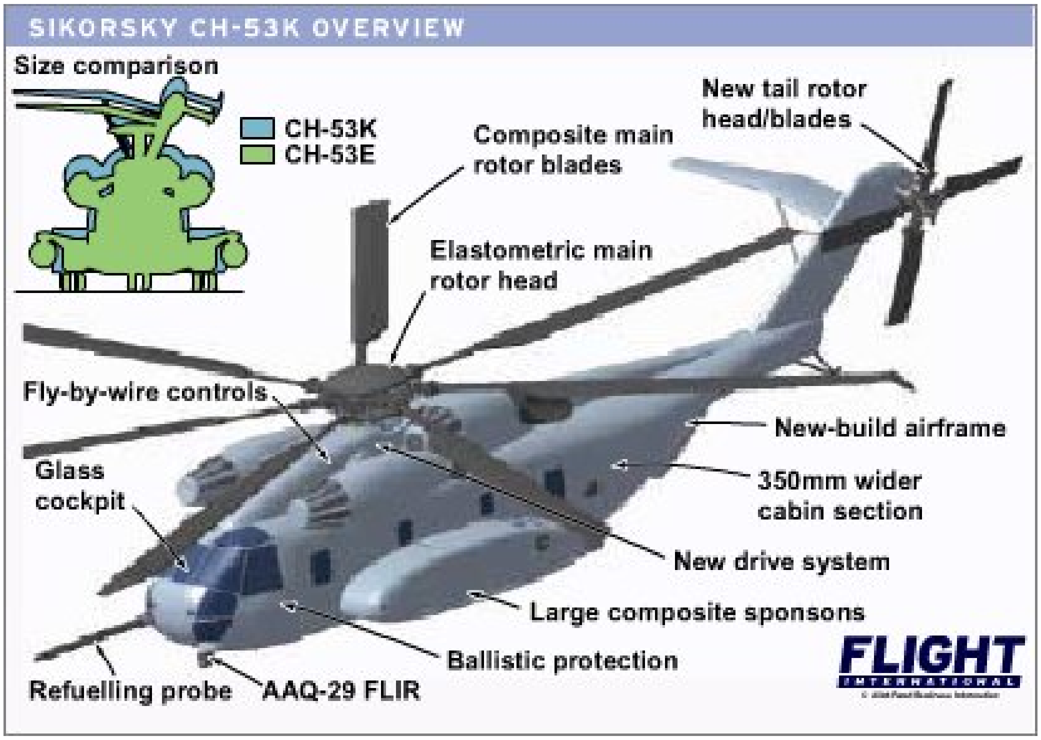

Figure 9. Upgraded Features of CH-53K within Equivalent Shipboard Logistical Footprint as CH-53E. Source: Warwick (2006).

Capabilities	CH-53K	CH-53E
Aircraft Specifications		
Empty Weight	43,750 lbs	37,500 lbs
Max Gross Weight	88,000 lbs	73,500 lbs
Useful Internal Payload	16,900lbs	13,200 lbs
Useful External Payload	27,000 lbs	15,000 lbs
Speed (Cruise/Max)	150 kts / 170 kts	130 kts / 150 kts
Configuration		
Payload	30 passengers 24 litters (12) 40"x48" pallets (2) full 463L pallets (5) half 463L pallets	30 passengers 24 litters (7) 40"x48" pallets
Armament	(3) GAU-21 .50 cal machine guns	(3) GAU-21 .50 cal machine guns
Network Systems	Link 16 VMF SATCOM	FBCB2 Blue Force Tracker
Aircraft Surviability Equipment (ASE)	DIRCM ALE-47 APR-39(D)V2	DIRCM AAR-47(v)2 ALE-47 DD Pods APR-39(D)V2
Mission Profile		
High/Hot/Heavy	3000' destination elevation 95°F OAT 27,000 lbs external load 110nm	3000' destination elevation 95°F OAT 9,628 lbs external load 110nm

Figure 10. CH-53K Compared to CH-53E. Source: U.S. Marine Corps Aviation (2019).

Although a heavier aircraft, the CH-53K is clearly a more advanced and capable aircraft compared to its predecessor which will help the USMC meet their increasing demands for heavy-lift capability (GAO, 2011b).

3. Operational Deployment

The CH-53 aircraft is designed to be organized into four squadron configurations that must be manned, trained, and equipped appropriately to execute the mission (U.S. Marine Corps Aviation, 2019). These four configurations are the 16-aircraft squadrons (1.0), 12-aircraft temporary squadrons (.75), 8-aircraft squadron minus (.5), and 4-aircraft detachments (.25; U.S. Marine Corps Aviation, 2019). A 1.0 squadron is a squadron operating at full capacity and can execute a .5 and two .25 missions simultaneously (U.S. Marine Corps Aviation, 2019). With only 142 CH-53E aircraft in the USMC inventory in 2019, most 1.0 squadrons are operating as .75 squadrons as the CH-53E continues to age (U.S. Marine Corps Aviation, 2019). The CH-53K's 2005 APB called for 156 aircraft and then was officially updated to 200 aircraft in the 2013 APB when the USMC adopted a force restructure plan to increase their personnel numbers by 28,000 Marines (GAO, 2011a). These 200 CH-53K aircraft will reincorporate the 1.0 squadron composition capability along with smaller squadrons by consisting of

- eight active Marine heavy helicopter (HMH) squadrons with 16 aircraft each,
- two reserve HMH squadrons with eight aircraft each, and
- one HMH training (MHMT) squadron with 21 aircraft. (U.S. Marine Corps Aviation, 2019)

With this composition, the USMC anticipates 165 of their 200 CH-53K's fully operating at any given time while 35 aircraft can undergo maintenance without disrupting the operational tempo. The USMC will likely request more aircraft after the CH-53K is fully operational. Often, these additional aircraft requests appear on an unfunded requirements list; however, the USMC has already anticipated requesting another 20 aircraft in their 30-year plan (Gertler, 2018).

Transition from the CH-53E to the CH-53K will take approximately 18 months for each squadron (U.S. Marine Corps Aviation, 2019). The USMC plans for the first CH-53K Marine expeditionary units (MEUs) to enact change of operational control (CHOP) in fiscal year (FY) 2024, which will set standard operating procedures with the new aircraft (*2019* U.S. Marine Corps Aviation, 2019). Although the CH-53K procurement quantity increased to 200 aircraft because of a USMC force restructure, the requirement for 200 aircraft remained even when the USMC conducted a follow-on force restructure that called for a decrease in 20,000 Marines (GAO, 2012). As the CH-53K emerges during the USMC personnel downsizing, it is essential for the USMC to assign trained personnel to the appropriate billets to ensure a smooth transition. Therefore, the USMC established CH-53K–specific military occupational specialties for pilots (7511) and enlisted maintenance personnel and aircrew (6053) in FY2018 to identify qualified Marines for critical billets (U.S. Marine Corps Aviation, 2019).

III. LITERATURE REVIEW

The purpose of this literature review is to familiarize the reader with the additional reports published on or about the CH-53K by government and non-government entities. The main parties featured in this chapter are the Government Accountability Office (GAO), Office of the Inspector General (IG), Congressional Budget Office (CBO), and Research and Development (RAND) Corporation. The GAO, IG, and CBO are independent organizations designed to examine federal agencies and provide objective feedback to improve efficiency. The GAO focuses primarily on the use of taxpayer dollars on behalf of Congress (GAO, n.d.). The IG is an office within the DOD that investigates matters regarding law violations and audits on government agencies (Office of the Inspector General, n.d.). The CBO analyzes budgetary and economic issues to provide reports and cost estimations that aid in the congressional budget process (Congressional Budget Office, n.d.). In contrast to the independent, government-affiliated GAO, IG, and CBO, the RAND Corporation is a nonprofit, nonpartisan organization that analyzes how public policy decisions impact world issues in security, health, education, sustainability, growth, and development (RAND, n.d.). On several occasions, the DOD has hired RAND to conduct research on the utilization of military assets and their respective costs.

A. GOVERNMENT ACCOUNTABILITY OFFICE

In April 2011, the GAO conducted a study of the CH-53K program, specifically analyzing changes in the program's cost, schedule, and ability to meet the warfighter's needs. The report analyzed the changes made to the program since its inception in 2005 and determined that most cost increases and schedule delays were due to the USMC's quantity increase from 156 to 200 aircraft (GAO, 2011b). Early delays were a result of miscommunication between the program office and Sikorsky about systems engineering requirements, difficulties with staffing both offices, and starting development before establishing a plan that achieved program requirements under the given DOD constraints (GAO, 2011b). Since costs increased approximately $6.8 billion from 2005 to 2011, mostly attributed to the quantity increase, the program office cut costs by postponing three performance capabilities and easing two maintenance technical specifications (GAO, 2011b). The three deferred capabilities were Link-16, variable message format, and Mode V which are all communications metrics that will be incorporated after the CH-53K's IOC (GAO, 2011b). The relaxed maintenance specifications were time requirements for mean time to repair and mean corrective maintenance time for operational mission failures (GAO, 2011b). Although potential solutions were proposed by Sikorsky to meet these specifications, the program office determined these specifications were not worth achieving at the expense of other program requirements and cost effectiveness (GAO, 2011b).

The acquisition life cycle recommends that the PDR, which validates that the proposed system is ready for development with an acceptable level of risk, should be completed within the TMRR phase, either before or after the DFRPRD, both of which are prior to Milestone B. The CH-53K program's original PDR date was set approximately 18 months after Milestone B, when the program had already started development, and then was delayed another 15 months (GAO, 2011b). GAO (2011b) attributes these delays to ill-defined requirements that caused confusion between the program office, the warfighter, and Sikorsky. In one case, the program office struggled to define software specifications for the avionics management system (GAO, 2011b). The program office noted how the use of a firm-fixed price (FFP) contract with Sikorsky's subcontractor Rockwell Collins for the avionics management system proved difficult to update, and adapting software specifications was also a challenge (GAO, 2011b). FFP contracts are typically used when the system is well-defined and has easily computable costs. The contractor assumes all the risk in these types of contracts since the DOD sets a fixed price of payment for the contract. Therefore, it is the sole responsibility of the contractor to minimize costs in order to make a profit (FAR 16.202, 2019). When the CH-53K avionics management system experienced design changes, the subcontractor was reluctant to implement changes for fear of driving up costs beyond the FFP, which led to further schedule delays. A consolidated list of subcontractors for the CH-53K main systems is provided in Appendix B.

Another example was confusion between the program office and Sikorsky about how the CH-53K should be C-5 aircraft transportable. Like its predecessor, the main gearbox and rotor of the CH-53K needs to be removed for the aircraft to fit within the C-5. However, the program office's intentions were that all aircraft components should travel within one C-5 aircraft, while the Sikorsky interpreted that the CH-53K body would transport in one C-5 while its gearbox and main rotor would transport in another (GAO, 2011b). This KPP was interpreted incorrectly by the contractor because the government did not translate the operational requirement into design specifications correctly, resulting in an ill-defined requirement (GAO, 2011b). Ultimately, the miscommunication was addressed, and the program proceeded under the program office's KPP requirement; however, this scheduling conflict resulted in cost increases during development.

The two relaxed KPPs were related to mean time to repair and mean corrective maintenance time for operational mission failure requirements that were deemed no longer cost effective for the program. Both metrics are a measure of the average amount of time required for the aircraft to be nonoperational for either repairs or maintenance. For instance, the CH-53K's two-piece rotor blade components require an excessive amount of time for the adhesive to secure, making the design not compliant to the original KPP. The proposed solution was to design a one-piece blade to minimize repair time; however, this solution increases the footprint of the aircraft on-board naval ships and drives up O&S costs by $99 per flight hour (GAO, 2011b). The trade-off for the program manager, after consultation with the warfighter/requirement community, was either to relax the time requirement or to increase costs throughout the program's life cycle. The USMC chose to relax the time requirement.

The 2011 GAO report found that the IOC's nearly 3-year schedule delay from September 2015 to June 2018 would result in a deficit of approximately 50 heavy-lift helicopters for the following 7 years as the CH-53E approached the end of its life cycle (GAO, 2011b). Since the report was published, the IOC date was pushed back two more times, ultimately to 2021.

B. INSPECTOR GENERAL

The DOD IG conducted a series of two audits assessing the acquisition management of the CH-53K. In their first report, titled *Increased Procurement Quantity for CH-53K Helicopter Not Justified*, they investigated how the USMC changed their procurement quantity from 156 to 200 aircraft, resulting in an additional $22.2 billion in anticipated procurement funding needs without adequate operational need or support from the appropriate authorities (IG, 2013a). The IG's second report, titled *CH-53K Program Management Is Satisfactory, But Risks Remain*, was published 5 months later and concluded that Naval Air Systems Command (NAVAIR) was effectively managing the program in accordance with defense acquisition guidelines, but technical challenges and postponed testing dates could result in additional cost growth and schedule delays (IG, 2013b).

The IG's concerns in the first report stemmed not from the increased procurement quantity itself but the lack of documentation the USMC could provide to justify their additional 44 aircraft. The IG concluded that Headquarters Marine Corps (HQMC) Department of Aviation did not follow the JCIDS approval process, failed to conduct studies that balanced operational need with affordability, incorrectly used the 2008 memorandum from the deputy commandant for aviation and the 2010–2011 Force Structure Review as justification for the procurement increase, and neglected to consider the impacts of the downsizing of personnel strength in the USMC (IG, 2013a). The USMC did not concur with any of the IG's findings.

The JCIDS process is used to identify capability gaps and solutions while considering program affordability and technological maturity (IG, 2013a). Part of the JCIDS process for any program is obtaining validation from the JROC for program requirements and capability documents, including procurement quantity increases. The USMC did not obtain direct JROC approval for the additional 44 aircraft but justified their increase with the JROC-approved CDD from December 2004, which delegated approval authority to the USMC for all non-KPP changes (IG, 2013a). The procurement increase was also approved by the MDA when the program requested a revised baseline in April 2013 (IG, 2013a). Despite these approvals, the IG concluded that these actions did not justify the increased quantity in accordance with the 2012 JCIDS, which asserts that programs should obtain revalidation from the JROC if they experience cost growth or quantity deviation greater than 10% (IG, 2013a). The increase from 156 to 200 aircraft resulted in about a 30% increase in quantity and a 54% increase in procurement cost (IG, 2013a). The USMC stated that the JROC did approve the USMC's plan to maintain nine active HMH squadrons (eventually changed to eight active and one reserve squadron) with 16 aircraft each and appropriate support aircraft, establishing the 200-aircraft quantity in the November 2007 brief titled *USMC Grow the Force Aviation Requirements* (IG, 2013a).

Another concern raised by the IG report was the lack of studies conducted by the USMC to justify their quantity increase. The report specifically addresses the 2006 Navy and USMC seabasing study—which did not include aircraft quantities—and the Marine Aviation Requirements Study (MARS), which was fiscally unconstrained and neglected aircraft quantities for training, backup, and attrition (IG, 2013a). The USMC argued that the approved nine HMH squadrons with 16 aircraft, for a total of 144 mission aircraft, logically resulted in a 200-aircraft procurement to include training, back-up, and attrition quantities. Additionally, the USMC noted that OPNAV Instruction 5442.8 authorized enough back-up aircraft to total a procurement quantity of 215 aircraft, but HQMC Department of Aviation accepted a lower quantity due to fiscal constraints (IG, 2013a).

The deputy commandant for aviation indicated the increase to 200 aircraft also aligned with the increase in USMC end strength to 202,000 Marines (IG, 2013a). However, a few years later, the USMC ultimately changed direction and planned to reduce end strength to 182,100 Marines by the end of FY2016 (IG, 2013a). IG officials questioned the USMC decision to maintain the 200 aircraft procurement even after the reduction in personnel. The USMC responded that end strength does not linearly correlate with aircraft procurement quantities and that operational commitments have remained the same, despite the decrease in manpower (IG, 2013a). Additionally, the number of Marines that make up a Marine expeditionary brigade (MEB) or MEU has not been affected by the end strength reduction (IG, 2013a). Furthermore, the CH-53K's primary mission for the MEB or MEU is not troop transport but equipment and vehicle transport; thus it cannot be correlated directly to end strength (IG, 2013a).

Five months later, the IG published their second audit of this series, stating that the program was being managed effectively and in accordance with defense acquisition guidelines (IG, 2013b). Their report concluded that program officials made appropriate decisions regarding technical milestones and testing, accurately reported cost growth and delays to the USD(AT&L) and Congress, and obtained the necessary acquisition program baseline (APB) approval to address their cost growth and schedule delay challenges (IG, 2013b). The primary concern raised by the IG report was the potential for future cost growth and schedule setbacks because of delayed testing (IG, 2013b).

The CH-53K program experienced its first significant schedule delay and APB update in 2010, when the program realized their original schedule was overly aggressive and was not conducive to meeting development goals (Naval Technology, n.d.-b). Initial flight testing was delayed for over a year because of technical deficiencies identified by the contractor, including component failures and contractor manufacturing challenges (IG, 2013b). Although these delays incurred additional cost growth, the IG report indicated that these were appropriate decisions considering the program's technical maturity (IG, 2013b). They also noted that these decisions were made in accordance with DOD Instruction 5000.2 (OUSD[AT&L], 2003), which encourages an event-driven process by requiring tests to be conducted when the system achieves its entrance criteria (IG, 2013b).

From January 2009 through July 2012, the program office submitted four program deviation reports to the USD(AT&L) reporting their experienced cost growth and schedule delays resulting from an aggressive original schedule, design challenges, increased procurement quantity, and better cost-estimating methods, respectively (IG, 2013b). Cumulatively, these factors caused the cost increases shown in Figure 11. Although approximately $22.2 billion of the $35.8 billion total life cycle cost increase can be attributed to the increase in procurement and O&S costs of the 44 additional aircraft, IG officials were concerned that this program saw significant cost increases prior to starting any flight testing (IG, 2013a, 2013b). The lack of testing up to this point also meant that the program's critical technologies (i.e., the main gearbox and main rotor blades) had not demonstrated performance in an operational environment (IG, 2013b). Best practices encourage a demonstration of successful performance for critical technologies prior to entering LRIP to prevent unnecessary cost growth and schedule setbacks.

Cost	2005 APB	2013 APB
RDT&E	$4.4B	$6.3B
Procurement	14.4B	22.2B
Operating and Support	52.1B	78.2B
Total Life-Cycle Cost	**$70.9B**	**$106.7B**
Program Acquisition Unit Cost[1]	$120.3M	$142.5M
Average Procurement Unit Cost[2]	$94.7M	$113.2M

[1] Program Acquisition Unit Cost is calculated by dividing the total acquisition cost by the total quantity.
[2] Average Procurement Unit Cost is calculated by dividing total procurement cost by the procurement quantity.

Figure 11. Comparison of 2005 and 2013 APB Costs. Source: IG (2013b).

The IG report also expressed concerns regarding the program's plan to conduct testing and production concurrently. In May 2013, the program office signed a $435.5 million cost-plus-incentive-fee contract modification with Sikorsky to produce four system demonstration test articles (SDTA) aircraft with delivery of the first aircraft due September 2016 (Defense Industry Daily Staff, 2020). These production-representative aircraft were to be used for initial operation and evaluation (IO&E), but ordering them while the program was still in its EMD phase risked increased costs and schedule delays if deficiencies were found while the aircraft were in production (IG, 2013b). Program officials indicated to the IG that this concurrency would only cause problems if the SDTA delivery dates were delayed, and if delivery delays occurred, they would likely impact IOC dates as well (IG, 2013b).

C. CONGRESSIONAL BUDGET OFFICE

In January 2020, the Congressional Budget Office (CBO) published a report on the cost of replacing the current naval aviation fleet in both size and capability through 2050.

Their projections anticipated that procurement costs through 2030 will average $11 billion, about 20% less than what we experienced in the 2010s (Trunkey et al., 2020). From 2030 to 2032, average procurement costs are expected to drop significantly, to an average of $7 billion per year due to completion of current purchases such as the F-35B/C, MV-22B, and the CH-53K (Trunkey et al., 2020). This drop in costs corresponds with the end of the average 30-year cycle in which the Department of the Navy (DON) will have replaced their entire fleet of approximately 4,000 aircraft (Trunkey et al., 2020).

The combined procurement costs of fighter/attack aircraft and the USMC's combat helicopters and tiltrotors make up more than 80% of the CBO's projected costs through 2050 (Trunkey et al., 2020). Replacement costs at the end of their respective service lives for the MV-22B, UH-1Y, AH-1W/Z, and CH-53E are projected at approximately $120 billion (FY2018 dollars), with the CH-53K leading the way for greatest cost per aircraft (Trunkey et al., 2020). For procurement alone, the CH-53K is expected to cost $19 billion (FY2018) from 2020 to 2028 and another $10 billion (FY2018) to replace the first 85 aircraft in the 2040s after its 25-year service life, as shown in Figure 4 (Trunkey et al., 2020).

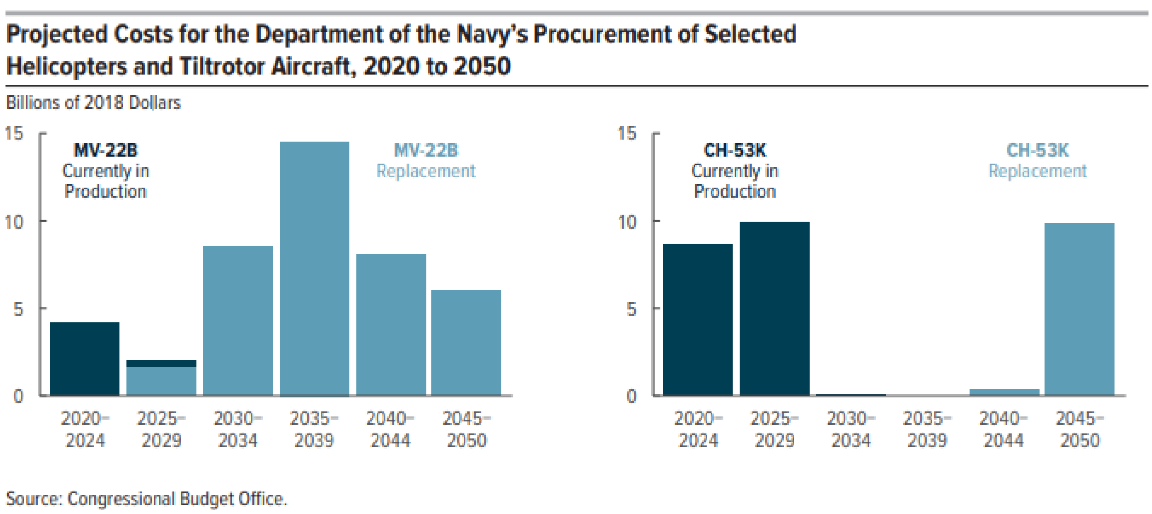

Figure 12. Procurement Costs of CH-53K Compared to MV-22B through 2050. Source: Trunkey et al. (2020).

The MV-22B will likely be replaced with a modified version of the same airframe, while the replacements for the AH-1Z and UH-1Y are based on the USMC interest in the Army's future long-range assault aircraft (FLRAA; Trunkey et al., 2020).

As of June 2018, the DON had 142 CH-53E helicopters with an average age of 30.2 years, and its youngest aircraft at 18 years old (Trunkey et al., 2020). The rapidly aging CH-53E and its role as the only heavy-lift helicopter in the DON is evidence of its need for replacement. However, balancing the CH-53E exceeding costs along with the other mission capability needs has posed a challenging future for the DON.

D. RAND CORPORATION

Seabasing is a military strategy designed to rapidly assemble Naval forces anywhere in the world when overseas bases or support from allies are limited (Parker, 2010). To strategically project power while remaining flexible in their operations, the USMC uses a Maritime Prepositioning Force (MPF) that is composed of surface ships, ship-to-shore craft, and airlift capability that is based on this seabasing strategy. In 2010, RAND published an analysis of alternatives for the composition of the MPF, which the USMC references as the Maritime Prepositioning Force Future (MPF[F]; Button et al., 2010).

The official definition of *seabasing*, as defined by the 2005 *Joint Integrating Concept*, is "the rapid deployment, assembly, command, projection, reconstitution, and re-employment of joint combat power from the sea, while providing continuous support, sustainment, and force protection to select expeditionary forces without reliance on land bases" (Department of Defense, 2005, p. 5). The USMC adopted seabasing as part of their 21st century amphibious warfare vision but has been largely unsuccessful in executing this concept since foreign policy demands shifted from the wars in Iraq and Afghanistan (Parker, 2010). Despite setbacks, the USMC is still moving towards this seabasing construct, especially as they consider possibilities for their MPF(F), and the CH-53K, with its superior heavy-lift capabilities, would be a critical asset to the success of this future strategy.

An ideal MPF(F) structure would be a 14-ship strike group joint operation between the USMC, U.S. Navy, and Military Sealift Command comprised of

- 2 LHA replacements, or LHA(R)
- 1 landing helicopter deck (LHD)
- 3 Lewis and Clark–class (T-AKE) cargo ships
- 3 large, medium-speed, roll-on/roll-off (LSMR) sealift ships
- 3 mobile landing platform (MLP) ships
- 2 MPF ships (Button et al., 2010)

Although effective, this composition is expensive and has affected the military's ability to fulfill other mission requirements. Alternatives for the MPF(F), proposed by RAND researchers, attempted to keep the operational capabilities intact while downsizing the assets required. One solution determined that eliminating an LHA(R) ship could be compensated by replacing the MV-22 tiltrotor aircraft with CH-53K helicopters (Button et al., 2010). This solution results in a gain of about three times the lift capacity with the CH-53K without sacrificing speed of external cargo transport (Button et al., 2010). The drawback is the lost speed from the faster MV-22 when it doesn't have an external load, typically during casualty evacuation situations when time is critical (Button et al., 2010). The CH-53K replacements for the MV-22 are not capable of counteracting the effect of eliminating both LHA(R) ships; however, using other platforms like the landing craft air cushion (LCAC) in conjunction with the CH-53K would maintain the same level of cargo transport capacity and save $5 billion in acquisition costs (Button et al., 2010). As demonstrated in this study, the uniqueness of the CH-53K's lift capacity makes the aircraft a necessity to operational forces while effectively reducing costs.

Another RAND study titled *Warfighting and Logistics Support of Joint Forces from the Joint Sea Base*, investigated the possibilities of modifying the CH-53K to MV-22 aircraft ratio in the MPF(F) (Button et al., 2007). Since the MV-22 and CH-53K can execute similar assault support missions, it seems redundant to develop the CH-53K when the MV-22 is already at FOC (Giordano, 2009). The advantage the MV-22 has over the CH-53K is its ability to travel over-the-horizon distances in fixed-wing aircraft mode at twice the speed of a helicopter, rapidly switch to helicopter mode, and transport Marines directly to the battlespace in seconds (Giordano, 2009). However, when the MV-22 uses its external cargo hook to carry its load, it loses its speed advantage over the CH-53K and only carries half the weight (Button et al., 2007). The CH-53K's aerial refueling capability allows it to achieve the same distance, albeit slower, but with more cargo, as the MV-22 (Giordano, 2009). In other words, the MV-22 is better suited for quick personnel movements, while the CH-53K is ideal for heavy-lift missions (Button et al., 2007). After analyzing a variety of different scenarios for MPF(F) needs, the RAND study concluded it would be advantageous to increase the CH-53K to MV-22 ratio as they foresee a greater need for heavy cargo transport with average speed personnel delivery over rapid personnel delivery with minimal cargo (Button et al., 2007).

E. DEPARTMENT OF DEFENSE

As required by 10 U.S.C. § 231a, the SECDEF submits an annual, long-term aviation plan that includes the military Services' fixed-wing, rotary-wing, manned, and unmanned aircraft for the next 30 years (DOD, 2018). Until the Pentagon discontinued the publication of this 30-year aviation plan in 2019, the plan provided foresight for budget planning and an inventory check for the approximate 14,000 aircraft flown by the DOD services (Sherman, 2019). The most recent published report covered FY2019–2048 and was based on the FY2019 President's Budget and the 2018 National Defense Strategy, which emphasized the need to counter threats in the Asia Pacific and European theaters while maintaining nuclear deterrence (DOD, 2018). Funding estimates in this report include RDT&E, procurement, O&M, MILPERS, and MILCON costs required to maintain and operate the aviation inventory.

The aviation funding plan highlights the benefits of the CH-53K transition because of its significantly decreased operating cost, aircraft efficiency, and operational effectiveness compared to its predecessor. The quantity requested of the CH-53K is 20 aircraft short of the requirement set by the capabilities production document (CPD). The CPD inventory requirement is calculated to maintain operational effectiveness of the squadrons while the individual aircraft undergo their standard O&M cycles. By procuring less than the 220 aircraft indicated by the CPD requirement, the CH-53K will experience inventory challenges like its predecessor (DOD, 2018). However, acknowledging the inventory procurement deficit in the 30-year aviation plan instead of merely on the unfunded requirements list indicates to many analysts that the USMC intends to fulfill this CPD requirement with a future procurement (Gertler, 2018).

IV. CASE HISTORY

On a cold afternoon in mid-January 2020, USMC Colonel Matthew Cruise sat in his office thinking about the events of the last few months. Cruise had been program manager (PM) of the CH-53K King Stallion heavy-lift helicopter for the last two years and the last several months had been the most challenging period in this tenure yet. Before Cruise arrived, the program had passed its Milestone C decision and was approved for low-rate-initial production. Since then, poor testing performance and several design changes had repeatedly delayed the CH-53K's initial operational capability (IOC) date to the warfighter. In December 2018, the program was tracking 126 technical deficiencies that required solutions to support a deployable configuration (Perrin, 2018). The most concerning of these deficiencies was a common problem for rotary aircraft called engine gas re-ingestion which can cause engines to stall mid-flight due to lack of clean air running through the engine (Eckstein, 2019b). Last month, a year after the engine gas re-ingestion issue was reported, Cruise's team finally found a deployable solution.

Despite this monumental program success, Cruise was still being pressured to provide answers to his superiors. Cruise ran his fingers through his hair at his desk with a heavy sigh and decided it was time to get input from his staff so he could write a lessons learned review of the program. After Cruise gathered everyone in the conference room, he posed the main question to them: Why had this program repeatedly failed to keep its baselines?

A. BACKGROUND

The CH-53K program, originally called the Heavy Lift Replacement program, was initiated in September 2003 after the USMC decided they needed an upgrade to their rapidly aging heavy-lift helicopter fleet (Perrin, 2019). Unique within the USMC aircraft inventory at the turn of the century, the CH-53E was the only helicopter capable of carrying three quarters of all USMC equipment from sea to shore (Laatsch, 2003). As the CH-53E aged (average age of operational CH-53E aircraft is 32.6 years) and equipment had gotten heavier, it became essential for the USMC to acquire a more capable heavy-lift helicopter to meet the logistical demands of future ship-to-shore operations (Laatsch, 2003; Reim, 2018). At the 2019 Senate Armed Services Seapower Committee, Lieutenant General Steven Rudder stated,

> If we look at the future of what this nation is going to have to do with the [National Defense Strategy] and distributed operations, you're going to need logistics; you're going to need heavy lift because we're going to be distributed, we're going to be eating a lot of gas, using up a lot of ordnance; and [the CH-53K] is going to be the ship-to-shore connector that's going to do it for us. There's nothing else out there in the inventory. (Defense Info, 2019)

Although the USMC was in dire need of a new heavy-lift helicopter, the program experienced many significant setbacks as it tried to produce an aircraft with three times the lifting capacity within the same shipboard logistical footprint. Many of these setbacks were the result of poor testing performance, which led to significant cost increases and numerous schedule delays. Figure 13 provides an abbreviated timeline of events for the CH-53K program; a full timeline is provided in Appendix A. Figure 14 is a calendar view of the program's major events from its 2019 Selected Acquisition Report (Perrin, 2019).

CH-53K Program of Record		
Year	Date	Event
2003	September	Completed AoA and initiated the Heavy Lift Replacement Program
2004	December	JROC approved CDD
2005	October	MS B Defense Acquisition Board complete
	December	USD(AT&L) approves entrance into MS B under $4.4B HLR program SDD contract
2010	January	Initial Design Review complete; preparations made for CDR
		USMC requests procurement quantity increased from 156 to 200 aircraft
	April	Initial flight delayed 2 years (2013) and IOC delayed 3 years (FY2018) because of overly aggressive initial program schedule
	July	CDR complete
2011	June	USD(R&E) approves post-CDR assessment and program enters Systems Capability and Manufacturing Process Demonstration
	August	Re-baseline: Schedule delayed for EDM, initial flight (2014), and IOC (2019)
2012	February	USMC retires CH-53D
2013	April	Re-baseline: request for increase to 200 aircraft approved
2015	October	First flight test complete
2016	October	IOT&E complete
2017	April	Defense Acquisition Board approves MS C; LRIP begins
2019	January	APB schedule breached and program deviation reported for TECHEVAL, IOT&E (OPEVAL), IOC and FRP Decision Review from poor testing performance and correction of deficiencies
	February	Schedule delayed for IOC (2021) and OT&E (2021) because of design deficiencies, specifically engine gas re-ingestion issue
	November	Updated APB approved
2020	January	Engine gas Re-ingestion issue resolved
2021		IOC
2023-2024		Deployment

Figure 13. Abbreviated CH-53K Timeline of Significant Events. Source: Perrin (2019); Defense Industry Daily Staff (2020).

Figure 14. Calendar View of CH-53K Program Major Events. Source: Perrin (2019).

In any defense acquisition program, the warfighter only cares about performance. However, the PM's responsibility is to manage the performance the warfighter wants with cost and schedule objectives set by budget constraints. Although Cruise had not been the only PM leading this program throughout its acquisition cycle, it was his responsibility to analyze what could be improved for future defense acquisition programs. He looked around the conference table and asked his test director, Arthur Grey, what his thoughts were about the performance of the CH-53K. Grey had been working in the CH-53K program much longer than Cruise had and he was well respected amongst his peers. Grey's perspective always provided Cruise with valuable insight and Cruise was curious on what Grey would have to say now.

B. PERFORMANCE

Grey responded, "From the beginning, the goal for the CH-53K was to exceed the CH-53E's performance in lift and range capabilities (Perrin, 2018). This is no easy task, especially when considering immature technologies for the design." He grabbed a whiteboard marker and quickly wrote the main performance requirements on the board.

The CH-53K can lift 27,000 lb for 110nm in high/hot environments and up to 36,000 lb, or three times the load of its predecessor, over shorter distances (U.S. Navy, 2019). Externally, the CH-53K's cargo hook can lift two HMMWVs, JLTVs, or a LAV while still carrying supplies or personnel internally (Marines, n.d.). The cargo hook can also be arranged to deliver three independent supply loads without reconfiguration (Marines, n.d.). The cabin is 12 in wider than the CH-53E allowing for larger supply pallets or an HMMWV transported internally (U.S. Navy, n.d.). Despite the larger cabin size, the CH-53K still has the same shipboard footprint as the CH-53E with lower operating costs per aircraft and fewer maintenance man hours per flight hour (U.S. Navy, 2019).

Compared to its predecessor, the CH-53K aimed for improvements in commonality, reliability, maintainability, interoperability, ship integration, survivability, and force protection (Perrin, 2018). For example, the CH-53K's engines provide 57% greater horsepower with 63% fewer parts, improving lift capacity and maintainability (U.S. Marine Corps Aviation, 2019). The aircraft's modern glass cockpit, fly-by-wire flight controls, and main rotor blades are all improvements found in the CH-53K that brings the airframe into the 21st century (U.S. Marine Corps Aviation, 2019). With the CH-53K, the USMC will be able to continue conducting missions in heavy-lift operations, support for refueling points, assault support, casualty evacuation, and recovery of downed equipment (Behler, 2019).

To achieve these program requirements, the CH-53K program followed the traditional major capabilities acquisition pathway within the adaptive acquisition framework and underwent numerous rounds of design planning, testing, and modifications to develop an aircraft that could meet the warfighter's needs. Figure 15 details the CH-53K's key performance parameters and how they have tracked throughout the program's updates (Perrin, 2019). Grey pulled this figure from his notes and taped it to the board next to his bulleted capabilities list for everyone to see.

Performance Characteristics								
	APB (Development) 12/22/2005		APB Change 1 (Development) 04/24/2013		APB (Production) 04/04/2017		APB Change 1 (Production) 11/26/2019	
Type	**Objective**	**Threshold**	**Objective**	**Threshold**	**Objective**	**Threshold**	**Objective**	**Threshold**
Net Ready (NR)								
KPP	Satisfy 100% of NR Reqts in JIA	Satisfy 100% of NR reqts designated as enterprise-level or critical in JIA	Satisfy 100% of NR Reqts in JIA	Satisfy 100% of NR reqts designated as enterprise-level or critical in JIA	Satisfy 100% of NR Reqts in JIA	Satisfy 100% of NR reqts designated as enterprise-level or critical in JIA	Satisfy 100% of NR Reqts in JIA	Satisfy 100% of NR reqts designated as enterprise-level or critical in JIA
Range & Payload (NM)								
KPP	110 w/30,000 lbs external load, no refuel	110 w/27,000 lbs external load, no refuel	110 w/30,000 lbs external load, no refuel	110 w/27,000 lbs external load, no refuel	110 w/30,000 lbs external load, no refuel	110 w/27,000 lbs external load, no refuel	110 w/30,000 lbs external load, no refuel	110 w/27,000 lbs external load, no refuel
Mission Reliability								
KPP	90%	89%	90%	89%	90%	89%	90%	89%
Logistics Footprint								
KPP	10% reduction from current CH-53E	<= current CH-53E	10% reduction from current CH-53E	<= current CH-53E	10% reduction from current CH-53E	<= current CH-53E	10% reduction from current CH-53E	<= current CH-53E
Sortie Generation Rate (SGR)/Average Sortie Duration (ASD)								
KPP	2.6 sorties/2.25 hrs	2.6 sorties/2.25 hrs	**(T=O) 2.6 sorties/2.25 hrs**	2.6 sorties/2.25 hrs	(T=O) 2.6 sorties/2.25 hrs	2.6 sorties/2.25 hrs	(T=O) 2.6 sorties/2.25 hrs	2.6 sorties/2.25 hrs

*** Denotes change in Objective/Threshold from prior APB**

Figure 15. CH-53K Performance Characteristics. Source: Perrin (2019).

Cruise interrupted, “Wait, are you telling me that for almost 15 years, this program’s performance characteristics were never modified or reduced?” Grey responded, “Not exactly. We made performance a priority in this program because the warfighter deserves the best capability we can provide. Unfortunately, achieving these capabilities was more challenging than we anticipated, especially in maturing some of the critical technologies. We ultimately maintained performance of the KPPs in the baseline but abandoned several of the most immature critical technologies in the early stages and only focused on two, but even these caused significant delays in the program. We also added a cybersecurity requirement to the system in 2017, over 10 years since the program began.”

The CH-53K program identified three critical technologies, none of which were fully mature when the program entered development in 2005. Early GAO reports showed the CH-53K with up to 10 critical technologies, but most were recategorized as noncritical or were integrated from other programs (GAO, 2007). The three remaining critical technologies were the main rotor blade, the main gearbox, and the main rotor viscoelastic lag damper, which prevents excessive blade lagging (GAO, 2007). The program office expected the viscoelastic lag damper to achieve maturity in 2009 but decided to abandon the technology altogether and replace it with a modified version of an existing and fully mature design (GAO, 2007, 2009). Instead, the CH-53K would have a linear hydraulic damper, which has only half the reliability of the originally proposed viscoelastic damper but twice the reliability of the current CH-53E damper (GAO, 2009). Despite the reduction in reliability of the linear hydraulic damper, this change still supported the 89% reliability KPP shown in Figure 15. Figure 16 tracks the technology readiness levels of these three critical technologies throughout the program.

Technology Readiness Levels				
	March 2007		March 2008	
Critical Technologies	Milestone B Assessment	Est @ Next Milestone	Milestone B Assessment	Est @ Next Milestone
Main Rotor Blade	TRL 4	TRL 7	TRL 4	TRL 7
Main Rotor Viscoelastic Lag Damper	TRL 6	TRL 7	TRL 6	N/A
Main Rotor Gearbox	TRL 4	TRL 7	TRL 4	TRL 7

Figure 16. Technology Readiness Levels for the CH-53K's Three Critical Technologies. Source: DAMIR PowerPoint Slides (March 5, 2007; March 5, 2008).

The remaining two critical technologies, the main rotor blade and the main gearbox, were expected to achieve full maturity by 2012 (GAO, 2007). After several delays due to design changes, both technologies achieved maturity in FY2018, nearly 6 years behind schedule (GAO, 2018). These two technologies accounted for many of the delays in the program and required schedule adaptations that were not consistent with best practices (GAO, 2016).

The main rotor blade was designated a critical technology because one of the CH-53K's requirements was for the aircraft to have the same shipboard logistical footprint as the CH-53E, but with better performance. However, with a heavier gross weight and load capacity, the CH-53K rotor blades required more vertical lift than the CH-53E. The 71% increase in power from the CH-53K's new engines helped achieve that additional vertical lift, but the rotor blades must also be designed to handle the increased power (Defense Industry Daily Staff, 2020). Initial designs started with a main rotor blade that was 6% longer than its predecessor, but that would increase the aircraft's logistical shipboard footprint (GAO, 2007). Eventually, designs settled on the same length main rotor blade with a 11% increase in width, creating 12% more surface area for the desired vertical lift ability (GAO, 2008; Defense Industry Daily Staff, 2020). The new designs on the main rotor blade tips improve hover performance and are easier to maintain (Defense Industry Daily Staff, 2020). The CH-53K's tail rotor blades were also modified for 15% greater surface area to increase thrust and balance with the more powerful main rotor (Defense

Industry Daily Staff, 2020). Small scale models of the main rotor blades were tested with exceptional results in 2009, but the full model could not be tested and considered fully mature until test aircraft were built due to a lack of wind tunnels large enough for the 79-ft (24-m) diameter (GAO, 2009). Further testing was conducted once the rotors were installed on the ground test vehicle (GTV; Defense Industry Daily Staff, 2020).

The main gearbox has always posed challenges in the design, development, and maintenance of rotary aircraft. Although other aircraft have used a similar and technologically mature main gearbox design for years, their expected load capacity is significantly less than the CH-53K requirement (GAO, 2008). In 2008, the main gearbox had achieved greater than 100% of its torque requirement but was not considered fully mature until 10 years later, when it was tested and modified to operate in a realistic environment (GAO, 2008, 2018). Main gearbox repairs are typically a depot-level repair because they are difficult and many of the spare parts are not stored onboard ships (Naval Air Systems Command, 2020). The increased reliability in the CH-53K main gearbox compared to the CH-53E will reduce maintenance costs and aircraft downtime. However, achieving that increased reliability comes with a significant cost associated with the unexpected additional testing required to solve its design deficiencies (Snow, 2019).

As Grey finished describing the testing challenges behind the program's critical technologies, Cruise asked for his professional opinion. "I understand these critical technologies were harder to achieve than we anticipated, but were the cost and schedule delays worth it?" Grey paused to consider and then replied, "Yes, I believe so. Both the warfighter and the taxpayer deserve results from this system. Without the additional financial investments and schedule deviations, we would not have been able to produce as system worth fielding for the next several decades." Cruise noted Grey's thoughts and changed the topic to more recent events. "What about the 126 technical deficiencies reported when I first arrived? Why were there so many deficiencies discovered so late in the testing process?"

The December 2018 SAR stated that the CH-53K was tracking 126 technical deficiencies required to achieve a deployable configuration (Perrin, 2018). The largest concern from these deficiencies is a common problem for triple engine rotary aircraft called engine gas re-ingestion, which is when hot gases from engine exhaust are re-ingested through the engine during flight (Eckstein, 2019b). Negative effects from engine gas re-ingestion include poor engine performance, degradation, overheating, and increased engine stalls, which can significantly impact life-cycle costs (Eckstein, 2019b). Sikorsky dedicated one test aircraft strictly to resolving this engine gas re-ingestion issue, while the other five test aircraft divided up the remaining 125 deficiencies (Eckstein, 2019b). Engineers suspected that the left engine exhaust was the culprit, but a test using colored oil smoke, shown in Figure 17, identified two engines whose exhaust would get caught underneath the dead space of the rotor where an engine intake was located (Eckstein, 2019b).

Figure 17. Colored Oil Smoke Test Identifies Cause of Engine Gas Re-ingestion Issue. Source: Eckstein (2019b).

In December 2019, a longer exhaust pipe with additional support was installed, and the program was officially back on track for IOT&E in 2021 and first deployment in 2023 or 2024 (Behler, 2019; Eckstein, 2019b). With the program's largest concern resolved, the

DOT&E recommended that the program complete the system development and demonstration (SDD) and LFT&E phases and develop a sustainable schedule for Follow-on Operational Testing and Evaluation (Behler, 2019). As for the other 125 deficiencies, Grey assured Cruise that they were minor deficiencies and that his team will have solutions for 106 of them before IOT&E begins (Behler, 2019).

“One last comment to add,” Grey said, “Cybersecurity concerns were a huge challenge for my team. When the program was initiated in 2005, there were no cybersecurity requirements detailed in the program’s documentation (GAO, 2020). These requirements were added in 2017 when the program was already very late in its development cycle (GAO, 2020). To address these late requirements, we modernized aircraft survivability equipment to better protect the data the aircraft has gathered and designed hardware to be easily upgradeable over the aircraft’s life cycle; however, it was a very difficult task to achieve when the aircraft’s design was already solidified (Behler, 2018). The GAO (2020) commented that late integration of cybersecurity requirements has often led to design challenges and increased program costs compared to including these requirements from the beginning. I agree, however, rapidly emerging cyber threats paired with lengthy contractual lead times add the risk of solutions becoming obsolete before they are even applied (GAO, 2018).” Cruise jotted a few notes down from Grey’s last statement and addressed another well-esteemed individual in the room, his financial manager, Robin Burke. She had been with the CH-53K program for a few years longer than Cruise and through most of the program’s financial setbacks. Cruise always appreciated her ability to speak the truth, even when it usually meant the program was in trouble.

C. COST AND SCHEDULE SETBACKS

“This program experienced many cost and schedule setbacks; however, not all of them were a result of poor performance testing as Mr. Grey just outlined. Many of these changes can be attributed to the program’s procurement quantity increases, late component deliveries, and facility changes,” Burke started. She taped a small schedule of events to the whiteboard next to Mr. Grey’s performance characteristics (see Figure 18). “This shows a comparison of the schedule changes from the original 2005 baseline to the current 2019 estimates (Defense Acquisition Management Information Retrieval [DAMIR], 2019). What we see from this is a 6-year delay for IOC and a 7-year delay for the FRP decision, which is not something senior leaders and the public are happy about."

Schedule Events				
Events	APB (Development) 12/22/2005 Objective/Threshold		APB Change 1 (Production) 11/26/2019 Objective/Threshold	
Milestone B DAB Review	Oct 2005	Apr 2006	Dec 2005	Dec 2005
CDR	Mar 2009	Sep 2009	Jul 2010	Jul 2010
Milestone C	Dec 2012	Jun 2013	Apr 2017	Apr 2017
TECHEVAL Complete	Oct 2014	Apr 2015	Dec 2020	Jun 2021
IOC	Sep 2015	Mar 2016	Sep 2021	June 2022
IOT&E (OPEVAL) Complete	Jun 2015	Dec 2015	Dec 2021	Jun 2022
FRP Decision Review	Dec 2015	Jun 2016	Nov 2022	May 2023
MDA Design Readiness Review	Apr 2009	Oct 2009	Deleted	Deleted

Figure 18. CH-53K Acquisition Program Baselines for Schedule. Source: DAMIR (2019).

Design challenges with the program's critical technologies (i.e., main rotor blades and main gearbox) and non-critical technologies led to early delays that repeatedly postponed the program's critical design review (CDR; GAO, 2010). The program office, in accordance with best practices, refused to enter the CDR until all subsystem design reviews were completed; however, this led to a delay of over a year to complete the CDR (GAO, 2010). To attempt to get the program back on schedule, the program office opted to eliminate noncritical tasks and defer three net-ready capabilities to production to save $103.5 million in development costs (GAO, 2010, 2011a). Deferring these capabilities—in this case, the variable message format, mode 5, and link 16, which are various systems for audio or visual military communication and threat identification—would be a trade-off to the warfighter because the initial aircraft will not have these capabilities until updates can be installed when the program reaches full production (GAO, 2011a).

The GTV began assembly in June 2011 and was delivered on time to Sikorsky in December 2012 (Defense Industry Daily Staff, 2020). However, design complications, late component deliveries, and part shortages for the GTV's testing stand contributed to another 1-year delay for the GTV's initial testing (GAO, 2015).

Best practices demand that at least 90% of the design drawings are released to developmental manufacturing prior to the CDR to determine the program's design stability (GAO, 2018). In 2010, 11,756 out of 17,622, or approximately 67%, of the expected drawings had been released, with the goal of achieving 90% prior to the program's design review in March 2011 (GAO, 2010). The GAO (2011a) reported the following year that this goal was achieved, and the design was officially considered stable as it entered the CDR. However, despite the repeated delays, it was determined at the CDR that the design was still unstable, to an unknown extent, and that they had only achieved a level of 89% released drawings, just short of best practice standards (GAO, 2018). The program did not collect traditional information about design stability for the GAO to track in its early stages, and it ceased collecting the stability data altogether after it falsely achieved its goal of 90% released design drawings, resulting in its unknown instability assessment at the program's CDR (GAO, 2009, 2017). The unexpected number of design changes required after the CDR, especially to noncritical technologies, caused further delays in testing and production as designs continued to be modified (GAO, 2017). However, the program deemed that these modifications would still allow the CH-53K to exceed all of its KPP (GAO, 2017).

Burke continued, "The largest program cost growth we experienced is when the USMC decided to increase their CH-53K procurement quantity from 156 to 200 aircraft in 2013. With nearly a 30% increase in quantity, we could expect a significant cost growth; however, these increases were questioned by the IG" (see Figure 19 and Figure 20). Figure 19 depicts how costs were allocated and expended over the course of the program in comparison to the quantity received. Since the USMC allocated more funds to compensate for their quantity increase, these changes did not cause expenditures to exceed the allocations (see Figure 19) despite the sharp increase in costs shown in change 1 of the development APB (see Figure 20). "Although the USMC planned and programmed for the additional aircraft and we re-baselined our numbers, the IG still considered these increases as unjustified," Burke noted.

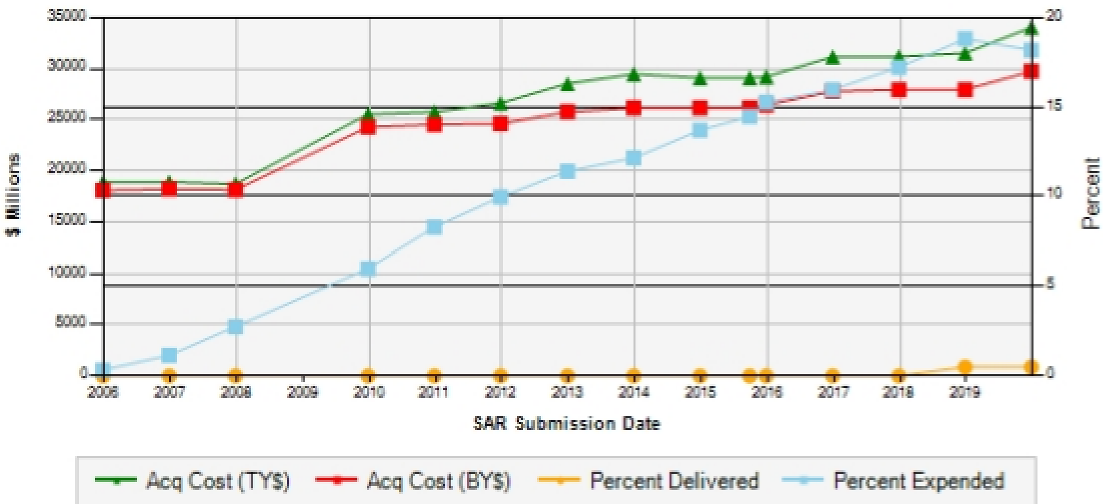

Figure 19. Program Acquisition Cost (Base Year 2017 $M). Source: Perrin (2019).

Cost Changes								
	APB (Development) 12/22/2005		APB Change 1 (Development) 04/24/2013		APB (Production) 04/04/2017		APB Change 1 (Production) 11/26/2019	
	Objective	Threshold	Objective	Threshold	Objective	Threshold	Objective	Threshold
Then-Year $M								
RDT&E	4366.4	N/A	6273.7	N/A	6957.8	N/A	8048.2	N/A
Procurement	14399.9	N/A	22178.8	N/A	24263.3	N/A	25812.5	N/A
MILCON	0	N/A	48.1	N/A	13.2	N/A	13.3	N/A
Acq O&M	0	N/A	0.0	N/A	0.0	N/A	0.0	N/A
Total Acquisition Cost	18766.3	N/A	28500.6	N/A	31234.3	N/A	33874.0	N/A
O&S	52062.7	N/A	78156.7	N/A	77882.8	N/A	81015.6	N/A
Total Life-Cycle Cost	70829	N/A	106657	N/A	109117	N/A	114890	N/A
Prog Acq Unit Cost ($M)	120.297	N/A	142.503	N/A	156.172	N/A	169.37	N/A
Avg Proc Unit Cost ($M)	94.736	N/A	113.157	N/A	125.069	N/A	131.696	N/A
Base-Year $M (BY2006)								
RDT&E	3962.0	4358.2	5535.9	6089.5	6018.2	6620.1	N/A	N/A
Procurement	11018.9	12120.8	16118.3	17730.0	16921.9	18614.1	N/A	N/A
MILCON	0.0	N/A	39.6	43.6	11.0	12.1	N/A	N/A
Acq O&M	0.0	N/A	0.0	N/A	0.0	0.0	N/A	N/A
Total Acquisition Cost	14980.9	N/A	21693.8	N/A	22951.1	N/A	N/A	N/A
O&S	23519.2	25871.1	37520.3	41272.3	38209.8	42030.8	N/A	N/A
Total Life-Cycle Cost	38500.1	N/A	59214.1	N/A	61160.9	N/A	N/A	N/A
Prog Acq Unit Cost ($M)	96.031	105.635	108.489	119.315	114.756	126.231	N/A	N/A
Avg Proc Unit Cost ($M)	72.493	79.742	82.236	90.46	87.226	95.949	N/A	N/A
Base-Year $M (BY2017)								
RDT&E	N/A	N/A	N/A	N/A	7265.0	7991.5	8233.3	9056.9
Procurement	N/A	N/A	N/A	N/A	20427.5	22470.3	21295.7	23425.3
MILCON	N/A	N/A	N/A	N/A	13.3	14.6	13.3	14.6
Acq O&M	N/A	N/A	N/A	N/A	0.0	0.0	0.0	0
Total Acquisition Cost	N/A	N/A	N/A	N/A	27705.8	N/A	29542.3	N/A
O&S	N/A	N/A	N/A	N/A	46188.9	50807.8	46261.2	50887.3
Total Life-Cycle Cost	N/A	N/A	N/A	N/A	73894.7	N/A	75803.5	N/A
Prog Acq Unit Cost ($M)	N/A	N/A	N/A	N/A	138.529	152.382	147.712	162.483
Avg Proc Unit Cost ($M)	N/A	N/A	N/A	N/A	105.296	115.826	108.652	119.517
Quantity								
RDT&E	4	N/A	4	N/A	6	N/A	4	N/A
Procurement	152	N/A	196	N/A	194	N/A	196	N/A

Figure 20. CH-53K Acquisition Program Baseline for Cost. Source: DAMIR (2019).

In May 2013, the IG calculated that the additional 44 aircraft resulted in an additional $22.2 billion in procurement and O&S costs (IG, 2013a). Another IG report compared the costs listed in the CH-53K APB from its initial procurement of 156 aircraft in 2005 to its increased 200-aircraft procurement, as shown in Figure 21 (IG, 2013b). The increase in RDT&E costs is attributed to the technical setbacks and schedule delays mentioned previously; procurement costs increased significantly because of the additional 44 aircraft, and O&S cost increases were a result of the additional aircraft, extended support duration, and a change in cost-estimation methodologies (IG, 2013b). After accounting for inflation, the GAO calculated that the CH-53K's total program costs increased 42.5% from 2005 to 2013, which was due largely to the increased procurement quantity (GAO, 2014).

Cost	2005 APB	2013 APB
RDT&E	$4.4B	$6.3B
Procurement	14.4B	22.2B
Operating and Support	52.1B	78.2B
Total Life-Cycle Cost	**$70.9B**	**$106.7B**
Program Acquisition Unit Cost[1]	$120.3M	$142.5M
Average Procurement Unit Cost[2]	$94.7M	$113.2M

[1] Program Acquisition Unit Cost is calculated by dividing the total acquisition cost by the total quantity.
[2] Average Procurement Unit Cost is calculated by dividing total procurement cost by the procurement quantity.

Figure 21. Comparison of 2005 and 2013 CH-53K APB Costs. Source: IG (2013b).

The IG also reported on the schedule delays that appeared in the program's updated APB. These delays are attributed to the technical setbacks stated previously as well as contracting delays and contractor staffing difficulties (IG, 2013b). Figure 22 outlines the schedule changes made from 2005 to 2013.

Program Schedule Milestones	2005 APB	2013 APB
Milestone C	December 2012	February 2016
Technical Evaluation Complete	October 2014	February 2018
Initial Operational Test and Evaluation Complete	June 2015	September 2018
Initial Operational Capability	September 2015	January 2019
Full-Rate Production Decision Review	December 2015	September 2019

Figure 22. Comparison of 2005 and 2013 APB Milestones. Source: IG (2013b).

"The GAO also reported on the program's cost and schedule setbacks and most attributed them to our technical complications," Burke added. "One report noted our change in acquisition cycle time from 119 months to 147 months from 2005 to 2013 (GAO, 2014). They also calculated that prior to the program's production readiness review in preparation for a MS C decision, the program had already experienced a 31.9% increase in schedule time (GAO, 2014)."

The program's first flight test was originally scheduled for FY2013, but the program did not begin assembly of the first EDM test aircraft until early 2012 (Defense Industry Daily Staff, 2020). Qualification testing failures with this first EDM model delayed the program's first flight test and created complications for the other three EDM models being assembled for future testing activities (GAO, 2015). Nearly 3 years behind schedule, the CH-53K accomplished its first flight test in October 2015 (GAO, 2016). IOC was delayed to late 2019 because of the late first flight; however, further complications with the main gearbox during flight testing delayed IOC until 2021, with deployment planned for 2023 or 2024 (Leone, 2019).

As the testing delays continued to compound on each other, the LRIP decision was postponed to March 2017, exceeding the program's delay parameters, which required the USMC to report to the USD(AT&L) (GAO, 2017). Typically, this scenario requires an immediate program re-baseline, but the USD(AT&L) decided not to require the re-baseline until after it achieved its LRIP decision (GAO, 2017). This allowed the program to demonstrate control of their manufacturing processes before production began, which helped provide a more accurate re-baseline of future costs and schedule goals (GAO, 2017). After successful test performances from the program's operational assessment (OA) in September 2016, the DOT&E supported the CH-53K's entry into production with the requirement that the engine design be modified to prevent overheating in certain conditions (GAO, 2018). The contract stated that each aircraft will cost on average $105 million with spare parts and services included (Defense Industry Daily Staff, 2020).

The CH-53K program was also delayed by a change in production facilities when Sikorsky was acquired by Lockheed Martin in 2015 (GAO, 2017). The CH-53K production line was moved from a United Technologies facility in Palm Beach, FL, to Sikorsky's headquarters in Stratford, CT (GAO, 2017).

The most recent analysis of cost and schedule changes was published by the GAO in June 2020 during their annual assessment for defense weapon systems (GAO, 2020). Figure 23 compares the CH-53K program's original 2005 estimates for 156 aircraft to the 2019 estimates and expenditures for 200 aircraft in FY2020 dollars (GAO, 2020). Since the program's initiation in 2005, unit costs and schedule (in months) have climbed 28.4% and 61.5%, respectively (GAO, 2020). The GAO reported the CH-53K at $157.6 million FY2020 dollars, which some sources have compared to the USMC variant of the Joint Strike Fighter, the F-35B, at $101.3 million for Lot 14 (GAO, 2020; Mizokami, 2017; Insinna, 2019).

Program Performance (fiscal year 2020 dollars in millions)

	First Full Estimate (12/2005)	Latest (09/2019)	Percentage change
Development	$5,045.21	$8,755.66	+73.5%
Procurement	$14,031.45	$22,643.06	+61.4%
Unit cost	$122.29	$157.06	+28.4%
Acquisition cycle time (months)	117	189	+61.5%
Total quantities	17	200	+28.2%

Total quantities comprise 4 development quantities and 196 procurement quantities.

Figure 23. Cost and Schedule Change Comparison. Source: GAO (2020).

“Overall, I would say several factors contributed to the numerous cost increases and schedule delays incurred within the CH-53K program. Poor performance in testing events, unstable designs, and increased procurement quantities led to most of these setbacks. Additional obstacles included late component deliveries, and contractor difficulties with employee staffing, a relocation in production line facilities. However, I consider many of these factors out of our control as the program office,” said Burke. Cruise noted Burke’s opinion and asked “What about foreign sales? How have those affected the program?” Burke sighed, “We took a hit in foreign military sales.”

D. FOREIGN SALES

In the early 1970s, Israel acquired the CH-53D and Germany the CH-53G, which have both undergone “Reset” programs similar to the USMC’s CH-53E’s (see the Operational Availability section for more information on the CH-53E Reset initiative) and are expected to complete their service life in the 2030s leaving both militaries in need of a new heavy-lift aircraft (Freedberg & Egozi, 2019; Lockheed Martin, n.d.).

“Competition has been tough in both Israel and Germany. Israel was debating between the CH-53K, Boeing’s CH-47F, and Bell-Boeing’s V-22 until budget constraints and the high priority of the F-35 halted all progress towards acquiring the V-22 in 2012 (Egozi, 2020). Until recently, we were only competing against the CH-47F Block II for Israel’s 20-aircraft procurement and Germany’s 44–60 aircraft procurement (Reim, 2020; Sprenger, 2020),” Burke stated.

From the Israeli government’s perspective, the CH-53K is not only competing with the CH-47F for the Israeli contract, but also for a spot in their country’s budget as they wish to procure additional ships and submarines from Germany to satisfy their increasing demands for missile defense capabilities (Egozi, 2020). The Israeli Air Force submitted a letter of request for pricing and availability of the CH-53K in January 2017 (Perrin, 2018). Since then, an Israeli test team of three pilots, a mechanic, and a program manager have been stationed at Patuxent Naval Air Station to test the new developmental and LRIP CH-53K aircraft to determine feasibility for their operational requirements (Freedberg & Egozi, 2019). Although the CH-53K would be a monumental upgrade for the Israeli Air Force compared to the current CH-53Ds, it comes at the cost of acquiring an entirely new aircraft since the two models do not share any similar parts (Freedberg & Egozi, 2019). Training, maintenance, and sustainment costs are all significant factors as they move forward in the selection process for their 20-aircraft procurement (Freedberg & Egozi, 2019).

To fulfill their heavy-lift requirements, Germany's Luftwaffe anticipated procuring their selected aircraft over an 8-year period with deliveries beginning in 2023 (Mader, 2019). Considering all the CH-53K delays, this was a tight timeline for the CH-53K to achieve and made the upgraded CH-47F an appealing option for the Luftwaffe (Mader, 2019). Although Sikorsky relied on their past success with the CH-53G and a strong German industrial base to seal the deal for this contract, Boeing also has 10 German companies on their side for the CH-47F (Lockheed Martin, n.d; Mader, 2019).

Burke said, "We anticipated the selection announcement from the Luftwaffe in 2021; however, a recent and surprise decision by the German Defence Ministry announced that Germany decided to walk away from both our program and the CH-47F, stating that selecting either aircraft would be uneconomical (Sprenger, 2020). Despite German officials' goals to keep defense spending high, this decision is likely a result of the unanticipated impacts of the COVID-19 virus (Sprenger, 2020). Therefore, we can no longer rely on Germany's contract to reduce our production costs."

Cruise nodded his head and looked towards his warfighter representative, Major Michael Matthews. As a seasoned USMC CH-53E pilot with several deployments to Iraq and Afghanistan, no one knows better than Matthews about what warfighters need and how fast they need it. Cruise asked, "Major Matthews, anything to add from your perspective?"

E. OPERATIONAL AVAILABILITY

"Sir, if I may be frank, our Marines needed these aircraft 6 years ago when this program first promised to deliver these aircraft. The delays in this program have caused disastrous effects to the current CH-53E platform which led to huge increases in operational costs for dwindling operational availability rates. Marines can't complete their missions when their aircraft are constantly down for maintenance and unless the CH-53K gets to them soon, they won't have much to work with," Matthews explained.

The current CH-53E aircraft are operating at three times the planned utilization rate, resulting in a faster attrition rate than expected and an increased need for the CH-53K (GAO, 2007). These attrition effects were partly due to pushing the airframe beyond its thresholds, which is why the CH-53K is designed with improved performance for heat, distance, and load capacity (GAO, 2008). To combat the rapid attrition of the current CH-53Es, the USMC initiated the CH-53E Reset program, which repairs aircraft back to the original off-the-production-line setting in order to reduce maintenance time and extend the service life of the aircraft to 2031 (Eckstein, 2019a). The numerous delays in the CH-53K program forced the USMC to consider the eligibility of the CH-53D aircraft for the Reset program as well, but they ultimately decided to retire the CH-53D in 2012 to reduce costs (GAO, 2011a; Defense Industry Daily Staff, 2020). This decision left the USMC in dire need of new heavy-lift helicopters.

In 2008, the USMC increased the procurement quantity for the CH-53K from 156 to 200 aircraft in accordance with their plan to expand personnel numbers from 174,000 to 202,000 Marines (GAO, 2011a). In March 2011, the USMC completed another force structure review that dictated they would reduce personnel numbers by 20,000 Marines in 2015; however, the USMC determined the 200 aircraft procurement was still justified despite an adverse IG report published in 2013 (see Chapter III; GAO, 2013). Despite the validated increase to 200 aircraft, the USMC is still short 20 aircraft as required by the program's CPD to fulfill operational effectiveness under standard maintenance cycles (DOD, 2018). This deficit will likely cause operational readiness challenges similar to those incurred by the CH-53E (DOD, 2018).

"I hope the CH-53K lives up to the reduced maintenance cycles and better reliability this program promised. Unless we procure more aircraft, I foresee being in this exact position 20 years from now," Matthews concluded.

F. CONCLUSION

Cruise thanked his staff for their time and walked back to his office deep in thought. With the program still not at IOC yet, Cruise sat with his head spinning given all the contributing factors that led to the CH-53K's current predicament. Senior leaders wanted to know why this program continuously failed to keep its baselines and recommendations to prevent the same mistakes happening again in future programs. What was he going to tell them?

Discussion Questions:

i) From the warfighter's perspective, why is the CH-53K important?

ii) Why did the program not meet its baseline?

iii) What setbacks in this program could have been avoided? How?

iv) How do media portrayals of the program affect the program?

v) How do foreign sales impact program decisions?

vi) What are the lessons learned from the CH-53K program that could be applied to future defense acquisition programs?

V. CONCLUSIONS AND RECOMMENDATIONS

The CH-53K is not only a substantial technological upgrade to the USMC's heavy-lift aircraft inventory, but also a remarkable engineering feat that enhances the warfighter's ability to fulfill operational requirements. Designing an aircraft with three times the lift capacity within the same dimensions as its predecessor pushes the boundaries of technological maturity and requires innovation and creativity to make it a reality. That being said, the performance setbacks experienced in this program, although costly, are normal and should be expected when squeezing every ounce of capability out of an airframe. Despite program setbacks and negative media attention, cost growth and schedule delays from technical challenges are common in defense acquisition programs. Key takeaways from this CH-53K case history are as follows:

- The defense acquisition process, along with its various interworking components and how they balance cost, schedule, and performance within a program, must be fully understood.

- Cost growth and schedule delays from performance setbacks should be anticipated for complex systems.

- Cost growth from increased procurement quantity does not indicate a program setback.

- Procuring a sufficient number of systems prevents significant life-cycle cost growth.

- Well-defined requirements are essential to meet warfighter needs and maintain program baselines.

Although these lessons are simply stated, they can be difficult to achieve in practice and their solutions go beyond the scope of this research. Although these lessons are simply stated, they can be difficult to achieve in practice, and their solutions go beyond the scope of this research. Further areas of research include investigating improvements for balancing the event-driven acquisition process with schedule-driven appropriation funding and examining cost estimation methodologies to account for predictable performance setbacks.

The aim of this case history was to provide acquisition students with a real scenario of how the defense acquisition system works in practice. This particular case, although unique in its own way, is similar to many MDAPs in the sense that it uses a complex process with numerous interconnected considerations and stakeholders that can complicate finding solutions to problems that arise within the program. The following sections offer conclusions regarding the acquisition of the CH-53K and the discussion questions posed at the end of the case history. They can be used to stimulate discussion among acquisition students about this case.

A. PERFORMANCE, COST, AND SCHEDULE

The role of the PM is to manage the "triple constraint," i.e., the cost, schedule, and performance of a defense acquisition program. Although the acquisition system is constrained by budgetary resources, performance is often the most important factor in the triple constraint and the PM will do what he/she can to achieve the performance criteria. This often requires letting cost and schedule goals slip, especially when technology is immature. The CH-53K case demonstrated this when poor performance during testing resulted in cost increases and schedule delays to correct the deficiencies found in testing. When dealing with immature technologies or complex systems, some level of test failure and rework should be expected to develop the system according to its specifications.

The CH-53K program encountered an issue with proper tracking of their released design drawings affecting the stability of the aircraft's design. Although it seems like a minor shortfall that the program only released 89% of their design drawings at CDR when best practices dictate 90%, the impact this shortfall had was significant on cost and schedule goals. The purpose of the CDR is to ensure a stable design before entering the production phase. Producing an unstable design, even in LRIP quantities, can still have a significant impact on cost and schedule when reworks are required to correct the design. Ensuring a stable design prior to MS C is essential to mitigating future cost and schedule setbacks.

CH-53K program documentation indicated that cost and schedule baselines changed several times throughout its development and production phases, but performance baselines remained the same (see Figure 15). However, the program deferred three net-ready capabilities – Link-16, variable message format, and Mode V – from IOC to FOC and relaxed the maintenance time requirement for mean time to repair and mean corrective maintenance time. Even though the maintenance time requirement was relaxed to maintain the logistics footprint KPP and the three net-ready capabilities were only deferred and not deleted, both the net-ready and reliability KPP baselines were changed, despite what top-level program documentation indicates. Further research is required to determine if, and to what extent, these lower-level changes affected the top-level performance baselines.

The comparison of the CH-53K to the F-35 in terms of unit costs was also another detriment to the CH-53K program, particularly because of how the data was presented. Despite these comparisons being numerically accurate, it is important to note that they are comparing the aircraft at different stages in their production lines. It is true that the CH-53K currently costs more than the Joint Strike Fighter, but the F-35 has had the added benefit of reducing unit costs through improved manufacturing processes. In other words, comparing the first few CH-53K aircraft, which will undoubtedly be the most expensive, to F-35B Lot 14 aircraft is a skewed perception. As greater quantities of any system are produced, unit costs will decrease as the manufacturing process becomes smoother and the production line exploits the benefits of economies of scale. When the F-35 was in its LRIP phase, unit costs for the U.S. Air Force's less-expensive variant were approximately $221.2 million in 2007, which is significantly more than the CH-53K's LRIP unit cost. (McCarthy, 2018). Attempts such as this to skew the data of a particular program can have negative effects on public opinion towards that system. A better method to analyze cost comparisons is to measure the percent change within the CH-53K program itself.

B. QUANTITY

Quantity procured can certainly affect program costs; however, increasing quantity does not mean the program has experienced a setback resulting from the failure to achieve its cost goals. As was done with the CH-53K program, any program that modifies their procurement quantity will need to re-baseline the program to the new quantity, so that percentage change comparisons can be tracked appropriately. However, the USMC justification for the quantity increase based on force structure reviews, personnel numbers, and end strength was inadequate in accordance with common practices and resulted in an adverse IG report. Instead of using constantly fluctuating personnel and end strength numbers, it would have been more appropriate to use the A_o calculation as justification for their quantity increase.

A squadron's operational availability (A_o) is measured by the number of fully mission capable aircraft they have at any given time (Office of the Chief of Naval Operations [CNO], 2003). A_o can be calculated in either of two methods: total uptime divided by the total uptime plus downtime or the number of systems that are ready divided by the total number of systems owned (CNO, 2003). A squadron's A_o varies throughout the year depending on maintenance cycles, deployment schedules, and aircraft type, so the following simplified example uses a fictitious A_o to illustrate the dilemma the CH-53K is likely to experience if the USMC does not acquire the additional 20 aircraft as required by the CPD to obtain full operational effectiveness (DOD, 2018).

If the USMC determines that they need 154 fully mission capable CH-53K aircraft at any given time with an A_o of 70% to fulfill their operational requirements, the program office can calculate with the A_o equation that the USMC needs 220 aircraft to sustain normal maintenance and repair cycles (CNO, 2003). However, when the USMC only procures 200 aircraft and operates at the same level, they achieve an initial A_o of 77% (CNO, 2003). When those initial aircraft need depot maintenance time, some aircraft will be forced to remain with the squadrons to work "overtime" so that the squadrons can meet their operational goals. This increases the mean time between maintenance (MTBM) and, ultimately, the mean down time (MDT) as those overtime aircraft experience longer depot times. The longer depot times will translate into a delayed maintenance cycle where operational aircraft experience even more increases in MTBM, resulting in an even greater MDT. This vicious cycle is exactly what required the CH-53E to undergo the Reset program and made the aircraft so expensive in its final years. Decreased aircraft inventory only exacerbates this problem and significant cost increases could be prevented with the

CH-53K if the program meets the CPD requirement. By failing to meet this CH-53K inventory requirement from the start, the USMC is likely to repeat history with a costly cycle of increased maintenance time per aircraft. Often, additional aircraft requests appear on an unfunded requirements list; however, the USMC has already anticipated another 20 aircraft in their 30-year plan (Gertler, 2018).

Foreign sales can benefit a program's cost goals by spreading the manufacturing costs over a greater quantity of systems that are not paid for by the U.S. government. In the same way that unit costs decrease as quantities are increased, foreign sales decrease unit costs for the U.S. procurement by exploiting economies of scale on the production line (Schogol, 2017). Therefore, the facilities' fixed costs will be spread among more than one buyer.

C. OTHER CONSIDERATIONS

Complications on the contractor's side also added to the program's challenges. In the program's early stages, Sikorsky struggled with staffing their offices with qualified personnel, causing delays in the aircraft's design development.

Sikorsky's ownership change from United Technologies to Lockheed Martin in 2015 also delayed the CH-53K program (GAO, 2017). The program's production line was moved from a United Technologies facility in Palm Beach, FL, to Sikorsky's headquarters in Stratford, CT which interrupted the flow of production (GAO, 2017). Not only did the Stratford facility require additional equipment and configuration changes to accommodate the new production line, but this relocation also occurred in the middle of assembly for the System Demonstration Test Articles (SDTA) aircraft (GAO, 2018). Sikorsky decided to complete the first four SDTA aircraft at the Palm Beach location and then transition to Stratford for the final SDTA aircraft (GAO, 2018). This interruption mid-assembly has contributed to the many complications in achieving statistical control in critical manufacturing processes, which is required for FRP (GAO, 2020). To certify that manufacturing processes are repeatable, sustainable, and consistent in producing quality aircraft, best practices indicate achieving statistical control of manufacturing processes prior to starting production (GAO, 2020).

D. DISCUSSION QUESTION ANSWERS

The answers to the questions below are designed to facilitate conversation among students and case readers about the defense acquisition process and the challenges MDAPs face when developing a suitable design to the warfighter. There are many stakeholder perspectives to consider, which can make defense acquisitions complicated. These answers are not all-inclusive but should guide conversation to discuss the considerations involved in balancing a program's cost, schedule, and performance criteria.

1. From the warfighter's perspective, why is the CH-53K important?

The heavy-lift capability for equipment, cargo, and personnel is essential for the USMC to conduct force projection and military operations. With the average age of the CH-53E at 32.6 years old, increased maintenance costs and aircraft down time have impeded the USMC's ability to conduct those operations (Reim, 2018). Despite efforts from the CH-53E Reset program extending aircraft service life to the 2030s, attrition rates are still impacting operational availability numbers and increasing the need for a new aircraft (Eckstein, 2019a). Also, heavier equipment, such as the HMMWV, JLTV, and LAV have necessitated and increased lift capacity (GAO, 2011b; Marines, n.d.). Lifting three times the load of the CH-53E, the CH-53K can lift 27,000 lb (12,247 kg) for 110 nautical miles in high/hot environments and up to 36,000 lb (16,329 kg) in less extreme temperatures (U.S. Navy, 2019). Additionally, its modern design should increase reliability and decrease maintenance time required to keep the aircraft operational. For example, the CH-53K's engines are built with 63% fewer parts than its predecessor which should simplify maintenance procedures (U.S. Marine Corps Aviation, 2019).

2. Why did the program not meet its baseline?

There are numerous reasons why the CH-53K program did not meet its baseline. As with any MDAPs that prioritizes performance, cost and schedule goals tend to slip as the program progresses throughout its life cycle. In this case, missed baselines can be attributed to both the program office and the contractor. The first schedule change was a result of the program office deeming the original schedule as overly aggressive and unattainable. Delays from poor testing performance are not uncommon in MDAPs, especially when several immature technologies are involved as seen with the CH-53K. Also, the falsely approved 90% release of critical designs prior to CDR led the program to proceed to LRIP without a stable design causing future performance failures in testing that exceeded cost and schedule goals. The late addition of cybersecurity requirements to the CH-53K caused significant cost growth and schedule delays as well. Contractor contributions to missed baselines include difficulties in staffing their facilities, a change in production locations during the CH-53K's production phase, and late component arrivals from subcontractors.

Other cost and schedule setbacks that were discussed in this case but did not affect program baselines are the increase in CH-53K procurement quantity by the USMC and the loss of foreign military sales to Germany. Although both these factors influenced the program's cost, neither should be considered as a "missed goal." The increase in quantity from 156 to 200 aircraft required the program to re-baseline their goals which is not the same as exceeding their thresholds. The loss of the potential CH-53K German contract forces the U.S. to accept more of the production costs per unit, but since foreign military sales are not guaranteed, the program should not have been anticipating this benefit in their cost estimations.

3. How do media portrayals of the program affect the program?

The media compared the unit costs of the CH-53K to the F-35B in 2020. Those costs were $157.6 million for the CH-53K and $101.3 million for the F-35B which depicts the negative image of a helicopter as more expensive than the most expensive aircraft acquisition program the U.S. government has ever funded (GAO, 2020; Mizokami, 2017; Insinna, 2019). The F-35, although a capable aircraft, has been portrayed negatively by the media throughout its entire life cycle because of its rapid cost growth throughout its development and deployment. Even though the cost comparisons between the CH-53K and the F-35 are accurate, the context has been significantly skewed to portray a negative outlook on the CH-53K. The unit costs of an LRIP Lot helicopter compared to a fighter jet in Lot 14 FRP in the same year are not equivalent comparisons. After FRP begins, unit costs decrease as manufacturing processes improve and economies of scale are implemented. The correct comparison to make is between the LRIP unit costs of each aircraft, in which case the CH-53K is much less expensive than the F-35. Media attention that skews data adds a negative and unnecessary stigma to the program that incorrectly sways public opinion and support for the program.

4. What setbacks in this program could have been avoided? How?

The program's original overly aggressive schedule could have easily been avoided but was luckily corrected early in the acquisition cycle. Although program funding from the PPBE process is schedule driven, it is important to balance that schedule with the event-driven process of the DAS. Meeting or exceeding performance specifications, especially on a complex system with immature technologies, will likely require numerous rounds of testing to improve its design. Program offices should plan for failures in test performance and allow the acquisition process to only proceed to the next phase when test events are accomplished instead of pushing through with an unverified system. The CH-53K program did schedule additional time for expected failures; however, the program office and the contractors likely underestimated the system's complexity and the number of tests required to achieve acceptable test results which led to missed cost and schedule goals.

Establishing all system requirements during the MSA phase is essential to development and design of the system. The CH-53K program added cybersecurity requirements to the aircraft in 2017, over 10 years after the program's MS B approval and concurrently with its MS C decision. MS C initiates production, so adding another performance requirement to the system's design after the system has completed its TMRR and EMD phases is guaranteed to add additional costs and schedule delays that were not anticipated when the program's baselines were made.

Finally, better internal controls in the contractors' and subcontractors' processes would have alleviated setbacks from late component deliveries and the falsely approved CDR based on an inadequate number of released design drawings. A program's CDR is to assess its design maturity for developmental manufacturing, such as prototypes, for the TMRR phase (DOD, 2020b). Best practices dictated 90% of drawings should be released prior to CDR to ensure a stable design; however, due to poor internal controls, the program thought they released 90% of drawings until an unstable design at CDR determined only 89% of drawings were released (GAO, 2018). This led to cost and schedule setbacks to correct deficiencies in non-critical technologies post-CDR and during prototype development.

5. How do foreign sales impact program decisions?

The U.S. started with an original procurement quantity of 156 aircraft and then increased to 200 aircraft in the 2013 APB (DAMIR, 2019). Assuming Germany was still bidding between the CH-53K and CH-47F, potential contracts from Israel and Germany could add anywhere from 20–80 CH-53K's to the program's production line (Reim, 2020; Sprenger, 2020). Therefore, fixed costs associated with the aircraft's manufacturing would be spread over a greater number of aircraft, ultimately lowering the U.S. CH-53K's average per unit cost. Germany's decision to pull themselves as a potential buyer of the CH-53K came at a cost for the USMC. The German procurement, if the CH-53K won over the CH-47, would have added an additional 25% to the production line and driven unit costs down as the production processes become more efficient over time (Schogol, 2017). With the CH-53K unit cost hovering around $131 million for aircraft in early lots, the costs saved in future lots as the production process improved would have been hugely beneficial to the USMC (Schogol, 2017). Israel's 20-aircraft procurement is currently the only other opportunity for the CH-53K to decrease production costs in the CH-53K. Although reducing costs comes at a benefit for the U.S. taxpayer, it is worth noting that foreign military sales should not drive program decisions directly. They can certainly benefit the success of the program, but, as shown in this case with Germany, foreign sales are not always a reliable source of cost reductions.

6. What are the lessons learned from the CH-53K program that could be applied to future defense acquisition programs?

"Big A" acquisition is a complex process when several intertwined components all hoping to achieve the same goal, but from different perspectives and priorities. An event-driven program is essential to mitigate excessive cost growth and schedule delays. If a system or subsystem fails a test event, additional funds will be required to correct its deficiencies, but it is more cost effective to make those corrections earlier rather than later when a production line is operating and numerous systems need to be corrected. The same concept applies to system requirements added after MS C, such as the cybersecurity requirements for the CH-53K. Implementing cybersecurity hardware and software into the CH-53K's design earlier in the acquisition cycle instead of after production began would have been more cost effective and likely produced a more suitable design for the warfighter.

Another key takeaway from this case is that procurement numbers affect a system's operational availability, maintenance cycles, and reliability. If there are not enough systems to execute missions and allow enough time for proper maintenance cycles, then the system will degrade faster which will lead to support complications during the O&S phase that the program office is still responsible for mitigating. Although the program office cannot demand the USMC or Congress to procure enough systems to alleviate future support challenges, they can start planning for potential solutions to anticipated problems.

Finally, understanding the impact media and public perception can have on a program's decisions and opportunities is beneficial to the success of the program. Senior leaders rarely have the time to learn all the details of a program and funding from Congress can be swayed by public support, or lack thereof, from constituents. Media portrayals on a program, whether accurate or skewed, can indirectly influence a program.

APPENDIX A. CONSOLIDATED PROGRAM OF RECORD TIMELINE

CH-53K Program of Record				
Year	Date	Stakeholder	Event	Est. Time of Completion
2003	Sep	Program	Completed AoA and initiated the Heavy Lift Replacement Program	
2004	Dec	Program	JROC approved CDD (formerly called Operational Requirements Document)	
		Sikorsky	Delivery order for time and materials to perform studies for HLR and Presidential Helicopter program	May-05
2005	Jan	Sikorsky	Receives cost-plus-fixed-fee contract for preliminary design	Jan-08
	Aug	Sikorsky	Cost-plus-fixed-fee contract for engineering delivery order	
	Oct	Program	Completed Milestone B Defense Acquisition Board	
	Dec	USD (AT&L)	MS B approval for $4.4B HLR program to enter SDD phase	
2006	Jan	Sikorsky	SDD contract awarded for CH-53K	
		Subcontractors	Contract awarded to Rockwell Collins for avionics management system	
			Contract awarded to Hamilton Sundstrand for auxiliary power units, environmental controls, and engine starting system	
	Apr	Sikorsky	Modification to prior cost-plus-fixed-fee contract for SDD of CH-53K to include 4 SDD aircraft, 1 GTV, and associated support	Dec-15
	Oct	Sikorsky	Sikorsky finds improved results to rotor design in testing	
	Dec	Subcontractors	General Electric selected for engine over Pratt & Whitney and Rolls Royce engines	
2007	May	Subcontractors	Aurora Flight Sciences, EDO Corp, GKN Aerospace, and Spirit AeroSystems selected for CH-53K fuselage after 12 mo. competition and multiple bids. Assemblies built for 7 test and certification aircraft (4 SDD, 1 GTV, 1 static test article, 1 fatigue test article)	Sep-15

CH-53K Program of Record				
Year	Date	Stakeholder	Event	Est. Time of Completion
	Jun	Subcontractors	Goodrich Corp. selected for electrical power generation and distribution system	
			Heroux-Devtek Inc. (Canadian manufacturer) selected for design and delivery of landing gears and tail bumper for SDD phase CH-53K articles	
		Foreign Sales	France & Germany confirm interest in heavy-lift helicopter programs. Choices between CH-53K, Boeing CH-47F, and Rosvertol's Mi-26T	
	Jul	Subcontractors	Eaton selected for hydraulic power generation system and fluid conveyance package	
	Sep	Subcontractors	Hamilton Sundstrand selected for secondary power systems	2009
			Donaldson Company selected for Engine Air Particle Protection System (EAPPS)	
	Nov	Subcontractors	Eaton selected for integrated fuel system	
2008	Feb	Subcontractors	Northrop Grumman selected for radar warning receiver integration program	2010
	Sep	Subcontractors	Breeze-Eastern Corp. selected for internal cargo winch system	
			Goodrich Corp. selected for IVHMS Health Usage and Monitoring Systems (HUMS)	
2009	Feb	Subcontractors	BAE Systems selected for cockpit seats, cabin armor systems, and integration with the fly-by-wire flight controls	
	Apr	Subcontractors	Curtiss-Wright Controls Inc. selected for multi-channel linear variable displacement transducers (LVDTs) for the fly-by-wire system	
	May	Subcontractors	Curtiss-Wright Corp. receives contract for data concentrator units	
	Jul	Subcontractors	GE38 completes engine testing in preparation for SDD phase testing	
2010	Jan	Program	Initial Design Review complete and preparations made for CDR	
	Feb	Subcontractors	Cobham selected for leading and trailing edge details for main rotor blade spar	

CH-53K Program of Record				
Year	Date	Stakeholder	Event	Est. Time of Completion
	Apr	Program	Growth: cost increase by 36.4% to $25,526.1M due to increase from 156 to 200 aircraft and a shift in schedule	
			Initial flight delayed 2 yrs and IOC delayed 3 yrs because of overly aggressive initial program schedule	Initial flight FY2013 IOC FY2018
	Jun	NAVAIR	Last delivery of CH-53D/Es from AMARG	
	Jun	Subcontractors	Raytheon Co. selected for 50 forward looking infrared devices to be fitted on CH-53E (42) and CH-53K (8)	
	Jul	Program	CDR complete	
	Sep	Subcontractors	GKN delivers first aft transition of fuselage	
	Nov	Subcontractors	ITT Corp (formerly EDO) delivers first pair of sponsons for fuselage	
2011	Jan	Sikorsky	Completes state-of-the-art virtual reality center to resolve design complications before CH-53K production	
	Feb	Subcontractors	Donaldson provides updates on EAPPS, initial DT exceeds expectations	
	Apr	Program	Contracts restructured from cost-plus award fee contract to cost-plus-incentive-fee contract	
	Jun	Program	USD(R&E) approves post-CDR assessment and program enters Systems Capability and Manufacturing Process Demonstration	
		Sikorsky	Begins assembly of first GTV	
	Aug	Subcontractors	GE delivers first GE38 engine for GTV	
		Program	Re-baselined: Schedule delayed for EDM, first flight, and IOC	Initial flight spring 2014 IOC 2019
	Dec	Subcontractors	Northrop Grumman selected for GPS/fiber-optic inertial navigation system	
2012	Feb	USMC	Retires CH-53D	
		Sikorsky	Modification to cost-plus-incentive-fee contract for CH-53K software	

CH-53K Program of Record				
Year	Date	Stakeholder	Event	Est. Time of Completion
		Subcontractors	Northrop Grumman receives contract to update software GPS/INS	
	Mar	Program	Estimated cost increased to total $3.4B because of increased testing, design complexity, and contract changes	
	Apr	Sikorsky	Modification to cost-plus-incentive-fee contract for CH-53K maintenance plans	
	May	Sikorsky	Modification to cost-plus-award-fee contract for LFT&E	
	Dec	Sikorsky	First GTV delivered for testing	
2013	Apr	Program	Updated APB re-baselines program after aircraft quantity increase approved	
	May	Subcontractors	Program office acquired T-408 engines directly from GE	
			GE receives firm-fixed-price delivery order for critical hard tooling for engines	
		Program	SAR released: cost increase primarily due to improved cost estimation analyses	
		Sikorsky	Modification to cost-plus-incentive-fee contract for 4 SDTA aircraft	Delivery 1st SDTA Sep-16 Initial flight late 2014
		IG	Adverse IG Report concludes program increase to 200 aircraft unjustified	
	Jul	Subcontractors	GE receives cost-plus-fixed-fee contract for time critical engine parts	Dec-16
	Sep	IG	IG Report “CH-53K Program Management Is Satisfactory, but Risks Remain” published	
		Subcontractors	Raytheon receives firm-fixed-price delivery order for CH-53K and USAF HH-60 sensors	
	Oct	Subcontractors	Kratos Defense & Security receives contract for development of maintenance trainers	
		Sikorsky	EVM penalty: Pentagon is withholding up to 5% of payments until Sikorsky corrects accounting deficiencies	

CH-53K Program of Record

Year	Date	Stakeholder	Event	Est. Time of Completion
			Completes initial testing on the rotors and ready for installation on GTV	
2014	Mar	GAO	Reports concerns with USMC scheduling CH-53K orders before testing is complete	
	May	Sikorsky	Begins full testing on non-flying GTV	
		USMC	Officially names the CH-53K aircraft the “King Stallion”	
	Jun	Program	PM leadership change from USMC Col. Robert Pridgen to Col. Henry Vanderborght	
	Jul	Subcontractors	GE receives firm-fixed-price contract modification for 16 engines	
2015	Oct	Program	First flight completed; 11 months behind schedule	
2016	Mar	Program	Flight testing continues; CH-53K achieves flight envelope expansion to 120 kts (goal cruise 150kts/max 170kts)	
	Apr	Program	DOD Advanced Acquisition Contract (ACC) awarded for LRIP Lot 1	
			CH-53K completes first flight under external load with 12,000lbs (goal 27,000lbs for 110nm)	
	May	Foreign Sales	Germany increases interest in CH-53K or CH-47F procurement to replace legacy CH-53G	
	Jun	Program	Requirement achieved: CH-53K flies 100ft above the ground with 27,000lb external payload	
	Aug	Program	Flight test for 4 EMD aircraft	
	Sep	Program	DOD contract awarded for an additional 2 SDTA aircraft for demonstration of mature manufacturing processes	
	Oct	Program	Initial Operational Testing complete	
2017	Jan	Foreign Sales	Israel requests pricing and availability for CH-53K	
	Mar	Lockheed Martin	Anticipates award of multi-billion-dollar contract from DOD for 200 CH-3K	
	Apr	Program	Defense Acquisition Board approves MS C status	
			APB update approved	

CH-53K Program of Record				
Year	Date	Stakeholder	Event	Est. Time of Completion
		Sikorsky	LRIP begins	
	May	Sikorsky	Modification to prior contract for support of LRIP for 4 Lot II aircraft	
	Jul	Foreign Sales	Sikorsky offers CH-53K to Germany for potential Direct Commercial Sales	
		Program	Long range flight test achieved	
	Aug	Sikorsky	Awarded LRIP Lot 1 for 2 CH-53K to USMC	Delivery by 2021
	Nov	Program	CH-53K redesignated from ACAT 1D to ACAT 1C program	
		Subcontractors	GE awarded contract for 22 LRIP Lot 1 and Lot 2 engines	Delivery by Jul 2021
2018	Feb	Foreign Sales	Sikorsky signs contract with Rheinmetall to compete in Germany's heavy-lift competition	
		Sikorsky	Modification to prior Navy contract for 7 LRIP Lot 3 aircraft	
	Mar	Foreign Sales	Sikorsky teams with German manufacturer MTU should Germany select the CH-53K	
	Apr	Foreign Sales	Sikorsky reveals German industrialization plan for air show competition	
	Oct	Sikorsky	Awarded contract for heavy repair of current CH-53E fleet	
	Dec	NAVAIR	Awards cost-plus-fixed-fee contract to Sikorsky for database of technical information of CH-53K	
2019	Jan	Program	Program Deviation Report (PDR) approved for schedule delays due to poor testing performance; TECHEVAL, IOT&E, IOC, and FRP all delayed	
			DON submits Above Threshold Reprogramming (ATR) request for $158M to Congress for delivery of deployable IOC configuration	
		Sikorsky	Modification to prior contract for maintenance support software	
	Feb	Program	IOC delayed due to design deficiencies	OT&E early 2021

CH-53K Program of Record				
Year	Date	Stakeholder	Event	Est. Time of Completion
	Mar	Program	Acquisition Decision Memorandum (ADM) approved for program restructure to prioritize SDD and provide deployable configuration for IOC	
	Apr	Sikorsky	Modification to prior contract in support of LRIP	
	May	Sikorsky	Contract to build 12 LRIP Lot 2 and Lot 3 aircraft	Delivery 2022
		Foreign Sales	Israel expresses interest in CH-53K	
	Jul	Sikorsky	Awarded two non-recurring contracts to support LRIP	Oct 2020 & Jan 2021
			Awarded firm-fixed-price delivery order for hydraulic fluid tanks	Sep-20
	Aug	Sikorsky	Awarded firm-fixed-price order for LRIP spare parts	
	Sep	Subcontractors	Modification to GE contract for 24 LRIP Lot 3 and 3 Lot 2 engines	Dec-22
	Oct	Sikorsky	Awarded firm-fixed-price delivery order for 36 CH-53E nacelles production kits	
	Nov	Program	Updated APB approved	
2020	Jan	Program	Engine Exhaust Gas Re-ingestion issue resolved	
	Feb	Sikorsky	Modification to prior contract for technical publications of Lot 2 aircraft	
			Modification to prior contract for non-recurring replacement of Electronic Counter Measure Systems	
	Mar	Sikorsky	Awarded firm-fixed-price advanced acquisition contract for 7 Lot 5 aircraft	Aug-21
	Apr	Subcontractors	Modification to GE contract for Engine Reliability Improvement Program for CH-53E	Dec-21
	May	Sikorsky	Modification to prior contract for pilot repair material, rate tooling, physical configuration audits, and associated systems for CH-53K production	
	Jun	Sikorsky	Modification to prior contract for logistics, management, and training	

CH-53K Program of Record				
Year	Date	Stakeholder	Event	Est. Time of Completion
			Order for update to existing CH-53K systems/subsystems	Oct-22
	Jul	Sikorsky	Modification to prior contract for pilot repair material	Jun-25
	Aug	Sikorsky	Awarded delivery order for non-recurring engineering for Maintenance Task Analysis Phase II	Aug-24
	Sep	Foreign Sales	Germany withdraws from competition	

APPENDIX B. CONSOLIDATED LIST OF SUBCONTRACTORS

Subcontractor	CH-53K Involvement
General Electric	T-408 Engine
Aurora Flight Sciences	Fuselage: Main Rotor Pylon
ITT Corporation (formerly EDO Corporation)	Fuselage: Tail Rotor, Side Sponsons
GKN Aerospace	Fuselage: Aft Transition (includes cargo ramp and overhead door assembly)
Spirit AeroSystems	Fuselage: Cockpit, Cabin
Goodrich Corporation	Electrical Power Generation & Distribution System: Generators, Controls, AC/DC Converters, Primary Power Distribution, Battery, External Controls; Integrated Vehicle Healthy Management System (IVHMS) Health Usage & Monitoring System (HUMS)
Heroux-Devtek Incorporated	Landing Gears, Tail Bumper
Eaton	Hydraulic Power Generation System, Fluid Conveyance Package, Integrated Fuel System
Hamilton Sundstrand	Secondary Power System: Environmental Control System, Auxiliary Power, Main Engine Start System
Donaldson Company	Engine Particle Protection System (EAPPS)
Northrop Grumman	Radar Warning Receiver: APR-39vX (selected by NAVAIR); Global Positioning System (GPS)/Fiber-Optic Inertial Navigation System (INS): LN-251 (selected by NAVAIR)
Breeze-Eastern Corporation	Internal Cargo Winch System
BAE Systems	Cockpit Seats, Cabin Armor Systems, Integration of Fly-by-Wire Controls
Curtiss-Wright Controls Incorporated	Multi-channel Linear Variable Displacement Transducers (LVDTs) for the Fly-by-Wire System, Data Concentrator Units
Raytheon	AAQ-29 Day/Night Surveillance Turrets, Memory Loader Verifier System Cables
Kratos Defense & Security	Maintenance Training Device Suite (MTDS), Helicopter Emulation Maintenance Trainer (HEMT)

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