U.S. GOVERNMENT ACCOUNTABILITY OFFICE

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November 5, 2020

The Honorable James Inhofe
Chairman
The Honorable Jack Reed
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Adam Smith
Chairman
The Honorable Mac Thornberry
Ranking Member
Committee on Armed Services
House of Representatives

Arleigh Burke Class Destroyers: Observations on the Navy's Hybrid Electric Drive Program

In 2009, the Secretary of the Navy established goals that, in part, focused on reducing the energy consumption of the Navy's forces. Two years later, the Navy initiated a program to develop and install Hybrid Electric Drive (HED) systems on its fleet of Arleigh Burke class (DDG 51 Flight IIA) destroyers. The Navy's HED system is designed to save fuel by using excess power from the ship's electrical system to propel the ship. Since 2011, Navy officials told us that they have spent over $100 million on the development, purchase, and upgrade of six HED systems.[1] However, the Navy has only installed one of these systems to date. In October 2018, the Navy completed installation of one of the systems on the DDG 103 (*USS Truxtun*). The other five systems that the Navy purchased are in storage. The Navy has not purchased the remaining 28 of the 34 original notionally-planned systems.

In July 2020, the Navy stated that, instead of installing the remaining five systems on ships, it would use them for a research effort referred to as Propulsion Derived Ship Service (PDSS). The Navy's goal for PDSS is to develop an electric motor that can facilitate the movement of power to and from a ship's electrical and propulsion systems, according to senior Navy officials. In contrast, the HED can only move power in one direction—from the electrical system to the propulsion system.

Senate Report 115-262 accompanying the National Defense Authorization Act for Fiscal Year 2019 asked the Navy to submit a report on the HED system installed on the *USS Truxtun* and

[1] A Navy official told us that they reprogrammed approximately $30 million of these funds for other purposes and cannot effectively spend an additional $32.5 million.

asked us to review the Navy's report.[2] According to the Senate report, the Navy was to conduct a comprehensive test and evaluation of the HED system, including six specific assessment areas, and report on the results to inform decisions about whether to continue with future HED installations on the DDG 51 class ships.

- Two assessment areas relate to HED investment information. The report asked the Navy to provide a summary of its planned investments for HED as well as an operating cost analysis.

- Four assessment areas relate to assessing HED performance through a comprehensive test and evaluation. The report asked the Navy to describe HED system use, summarize daily operational reports, compare two DDG 51 class ships that could be used to ascertain fuel savings, and provide metrics that evaluate HED during operations.

Subsequent to your direction in the report, you also asked us to provide information on the Navy's recent decision to restructure the HED program and use the five existing HEDs for the PDSS research effort. This report: (1) assesses the extent to which the Navy's report on the *USS Truxtun* included information regarding the assessment areas as requested by Congress, and (2) describes the Navy's decision to suspend the HED program and use the HED systems for the PDSS research effort.[3]

To assess the Navy's report on the HED system, we reviewed the Navy's January 2020 report to Congress and analyzed data used to create the report. We obtained the Navy's 2013 business case analysis for the HED program and assessed whether the information contained in this analysis could inform program decisions. We also analyzed whether the 2013 business case was still current. We obtained and evaluated other program documents, such as requests for information from Congress and memos about the program's expectations, which had been used to guide and justify the previous investments the Navy made in the HED program. In addition, we assessed the performance information in the Navy's report to determine the extent to which this information was based on a comprehensive test and evaluation. We assessed relevant documentation, including developmental test reports and engineering documentation. We also spoke with officials from the Navy's test agency and compared the HED approach with the test agency's guidelines.

To describe the Navy's decision to suspend the HED program and pursue the PDSS effort, we spoke with Navy officials and reviewed the only document the Navy provided that was relevant to its PDSS effort. For both objectives, we spoke with officials responsible for managing the HED modernization, fleet engineers, the commanding officer and other crew of the *USS Truxtun*, other fleet officials, and the Chief of Naval Operations' requirements officials. We determined that the data we used are reliable for the purposes of describing the HED system's performance and costs.

We conducted this performance audit from February 2020 to November 2020 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for

[2]S. Rep. No. 115-262, at 142 (2018).

[3] Naval Sea Systems Command. *Report to Congress: Performance Assessment of the Hybrid Electric Drive (HED) Onboard the USS Truxtun (DDG 103)*. (Washington, D.C.: Jan. 1, 2020).

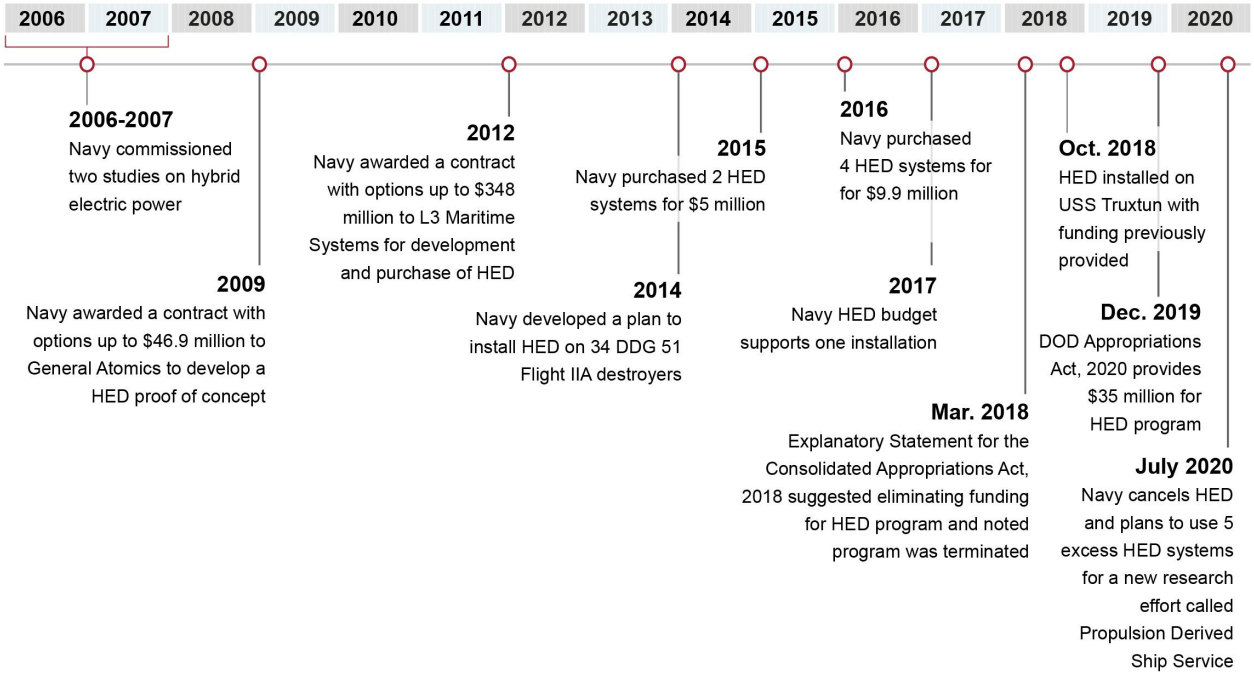
our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Navy Arleigh Burke class destroyers use one set of gas turbine engines to generate electricity (generators) and another set of gas turbine engines (engines) to propel the ship. The HED motor draws surplus power from the ship's electric generators and uses it to propel the ship. This allows the crew to turn off the engines typically used to propel the ship, thereby saving fuel. While running generators and the HED motor is more efficient than running generators and engines, the trade-off is that the HED system can only propel the ship at a maximum speed of 11 knots (a destroyer has a max speed of 30 or more knots when using its main engines). Navy engineers stated that they designed the HED system to have a maximum speed of 11 knots because a large percentage of a ship's hours spent at sea are at speeds of 11 knots or below.

The Navy has received at least $62.5 million to research and develop the HED motor and an additional $112.5 million to buy six HED systems and install one of them on the *USS Truxtun*. Of this $175 million, Navy officials told us that they spent approximately $108 million on developing and purchasing HED systems and plan to spend about $2.5 million to upgrade them. A Navy official told us that they reprogrammed approximately $30 million of these funds for other purposes and cannot effectively spend an additional $32.5 million. In July 2020, the Navy suspended the HED program. Figure 1 illustrates the timeline of major events during the Navy's acquisition of HED systems.

Figure 1: Hybrid Electric Drive (HED) Acquisition Timeline



Source: GAO summary of Navy and Congressional data. | GAO-21-79R

Text of Figure 1: Hybrid Electric Drive (HED) Acquisition Timeline

Timeline:

- 2006-2007 - Navy commissioned two studies on hybrid electric power
- 2009 - Navy awarded a contract with options up to $46.9 million to General Atomics to develop a HED proof of concept
- 2012 - Navy awarded a contract with options up to $348 million to L3 Maritime Systems for development and purchase of HED
- 2014 - Navy developed a plan to install HED on 34 DDG 51 Flight IIA destroyers
- 2015 - Navy purchased 2 HED systems for $5 million
- 2016 - Navy purchased 4 HED systems for for $9.9 million
- 2017 - Navy HED budget supports one installation
- Mar. 2018 - Explanatory Statement for the Consolidated Appropriations Act, 2018 suggested eliminating funding for HED program and noted program was terminated
- Oct. 2018 - HED installed on USS Truxtun with funding previously provided
- Dec. 2019 - DOD Appropriations Act, 2020 provides $35 million for HED program
- July 2020 - Navy cancels HED and plans to use 5 excess HED systems for a new research effort called Propulsion Derived Ship Service

Navy's Report Did Not Include All of the Information Requested by Congress

The Navy's January 2020 report to Congress included some performance information but did not provide a summary of planned investment or an assessment of the HED system's benefits such as enhanced mission effectiveness following comprehensive test and evaluation, as requested.

Navy's Report Did Not Provide Assessment of Costs and Benefits of the HED System

The Navy did not include a summary of the investment planned for the HED system in its January 2020 report, as requested by Congress. Specifically, the report did not contain an assessment of the costs and benefits of the HED system or an assessment of the funding needed to execute the program. The Navy commissioned a business case analysis in 2013 and an update to this analysis would have included an assessment of the costs and benefits of the HED system.

The Navy stated that it did not include a summary of the planned investment in its report because the HED program was not included in the President's fiscal year 2020 budget request and also due to the need for additional HED system data. However, as noted above, Congress appropriated $35 million in funding for the HED program in 2020.[4] Navy program officials stated that they cannot use this funding to upgrade and install the five previously purchased HEDs before the funding expires. Navy program officials told us that it will likely take over 3 years to upgrade the HED system, make changes to the ship's software, and integrate the HED system into a ship's maintenance planning. Further, Navy officials stated that they could not responsibly

[4] Consolidated Appropriations Act, 2020, § 8006, Pub. L. No. 116-93, 133 Stat. 2317, 2335 (2019). The programs contained in the tables in the explanatory statement, for which the obligation and expenditure of amounts appropriated in this Act exceed the amounts requested, are required to be carried out in the manner provided to the same extent as if the tables were included in the text of the Act. The explanatory statement table for Division A -- Department of Defense Appropriations Act, 2020 indicates a $35 million increase in Other Procurement funding is for the HED program.

spend these funds to prepare for HED installations for which there was no planned funding. The Navy now plans to use $2.5 million of these funds to upgrade the five previously purchased HEDs before sending these systems back to the Navy's engineering lab for its PDSS research effort.

In its January 2020 report, the Navy did not estimate whether the HED would have yielded benefits to justify further investment in the HED program. In 2013, the Navy commissioned a business case analysis for the HED system, which contained an assessment of the cost and benefits of the system and its potential funding needs. In this study, the Navy found that the HED system would likely pay for itself in fuel cost savings after 12 to 17 years of usage if it purchased and installed the 34 HEDs as notionally planned. However, the Navy has not updated this initial analysis since 2013 and key factors have changed over the last 7 years, including:

- the current and forecasted price of fuel,
- the age and expected service life of DDG 51 Flight IIA ships, and
- the Navy's strategic priorities.

In a February 2020 written response to Congressional committees' questions regarding the lack of cost and benefit information in the Navy's January 2020 report, the Navy presented best-case and worst-case scenarios for the potential cost savings per year. According to the data the Navy provided to members of Congress, it could take between 14 and 81 years for the HED system to save enough fuel to surpass costs and yield a positive return on investment.[5] Most DDG 51 Flight IIA destroyers have approximately 20 to 32 years of service life remaining before they are decommissioned. As such, additional data is needed to determine whether the system can be purchased and installed on ships with sufficient time to recoup all or a significant portion of the costs.

In April 2020, we briefed your staff on our preliminary findings associated with this review. Subsequently, a June 2020 Senate report—accompanying a bill for the National Defense Authorization Act for Fiscal Year 2021—directed the Secretary of the Navy to provide a report on the plan for HED installation, testing, and operational use on Arleigh Burke class destroyers after the fiscal year 2022 budget is submitted to Congress.[6] The Senate report states that the Navy report is to include the following, among other things: (1) a plan to develop requirements for HEDs on naval vessels; (2) the installation schedule for existing HED systems, including fiscal year and hull number; and (3) the HED-related funding requirements by fiscal year and the extent to which such requirements are fully funded in the future years defense programs. This report, if provided by the Navy, could furnish information necessary for planning the future of the HED program.

Navy's Report Provided Some Performance Information but Was Not Based on Comprehensive Testing

In the January 2020 report, the Navy included information on the performance of the HED system from operations on board the *USS Truxtun* during an 8 month deployment completed in 2019. The Navy stated that the HED system could save up to 204 gallons of fuel per hour, or

[5]We added the cost to purchase and install HEDs provided by the Navy and divided it by cost savings estimates from the Navy scenarios to derive the number of years it would take for HED to yield a positive return on investment based on the data the Navy provided to Congress.

[6] S. Rep. No. 116-236 (June 2020).

about 34 percent of the fuel usage, when the ship is travelling at low speeds. Further, the report stated that greater HED usage would enable a ship's crew to stretch limited fuel budgets and remain at sea for longer durations. The data from the *USS Truxtun*'s second deployment in spring 2020 is consistent with the first deployment and was used to support the Navy's January 2020 report to the congressional committees. As of September 2020, the ship's crew told us they had used the system for a total of 366 hours from March through July 2020, and that the system functioned effectively. The crew told us that they saved approximately $329,000 in fuel during this time period as a result of using the HED.

The ship's crew also told us that they used the HED system about 22 percent of the time they were operating in March and April 2020 until they experienced a system failure—not related to the HED—that curtailed its usage. The crew members added that the HED has been reliable and useful for the ship's current mission, as it has continued to allow the ship to stay at sea for longer periods.

In its January 2020 report, however, the Navy stated that the HED performance information collected thus far cannot be used to draw conclusions about the HED's overall performance. The Navy stated in this report that HED performance data was limited and insufficient to determine the overall performance of the system, although the Senate report had directed the Navy to conduct a comprehensive test and evaluation assessment of the HED installation on the *USS Truxtun*. A comprehensive test and evaluation is an assessment of a system's performance, reliability, and cyber survivability, typically conducted by the Navy's Commander of Operational Test and Evaluation Force, to inform program decision-making. Instead of conducting a comprehensive test and evaluation, Navy program officials stated that they planned to operate the HED system for a period of 8 months to gain data on its performance and reliability. However, this first attempt to collect data on the HED system during ship operations was curtailed to 5 months by a seal failure in the HED system that caused an oil leak.[7]

The Navy's January 2020 report could only characterize HED performance based on 82 hours of operational data. Navy program officials told us in April 2020 that they do not know how many hours of testing would be required to understand the system's performance and reliability, and they have no process for determining how much run-time is sufficient to make conclusions about the HED's performance and reliability. In contrast, a Navy test official told us that they have many ways to test systems that can provide timely information and comprehensive results without adding significant cost and time to the project. Without a comprehensive test and evaluation, the Navy does not have sufficient data to make an informed decision about the future of the HED program. In the June 2020 Senate report accompanying a bill for the National Defense Authorization Act for Fiscal Year 2021, the Secretary of the Navy is directed to provide a report that includes a test plan approved by the Navy's Commander Test and Evaluation Force.

Navy Is Suspending HED Program to Support a Research Effort without Analysis to Support Its Decision

We are not able to fully describe the Navy's decision to suspend the HED program and use it for PDSS research because (1) we found a lack of documentation regarding the PDSS effort and

[7] The Navy could not repair the system at-sea; therefore, the system was not used for the remainder of the mission, which ended in October 2019. Following the *USS Truxtun*'s deployment, the original equipment manufacturer redesigned the seal and the Navy installed it on the *USS Truxtun* in December 2019.

(2) the information we obtained on HED performance and benefits differed from the Navy's justification. In June 2020, Navy program and requirements officials informed us that they were no longer planning to install the five previously purchased HED systems on DDG 51 Flight IIA destroyers. Instead, these officials stated that they plan to use these HED systems for research into a different electric motor, known as PDSS. However, these officials also told us that they have no documentation associated with the PDSS effort—that is, there are no requirements or cost and schedule expectations. Lastly, Navy program and requirements officials also stated that they did not have a memorandum from leadership indicating a proposed plan for the effort. In July 2020, the Navy responded to a congressional request for information on HED installation and stated that it intended to transfer the HED systems for use in PDSS research. Senior Navy leadership provided this response to us in September 2020 and it is the only documentation we have been provided regarding the PDSS effort.

In a June 2020 meeting with the Navy, HED requirements officials told us of several reasons they are suspending the HED program. However, the Navy is suspending the program without completing analysis that determines its costs, benefits, and performance, which is necessary to justify such a decision. Such analysis usually provides a foundation for these types of program decisions. Specifically, during the course of our review, we obtained information that differed from the rationale provided by Navy officials to justify suspending the HED program. Table 1 compares the Navy's statements explaining why it is suspending the HED program to the information gathered during our review.

Table 1: Navy Officials' Statements about Suspending the Hybrid Electric Drive (HED) Program Compared with Our Observations of the HED System

Navy requirements officials' rationale	Information GAO gathered during our review
It is expensive to maintain the HED system.	Some maintenance requirements require effort and cost to complete. The crew of the *USS Truxtun* stated that, while conducting operations and using the HED system for 6 months between March and July 2020, the system required minimal maintenance. In all, without more comprehensive testing, the cost of maintaining the system is not known.
The Navy cannot use the HED system very often in operations.	HED can be used when the ship is travelling at speeds up to 11 knots. The Navy's January 2020 report stated that this represents about one-third of a typical DDGs operating profile.
The Navy can opt to go back and install a version of HED on DDG ships.	According to the 2013 HED business case, as the DDG fleet ages and ships approach the end of their service lives, it becomes less likely that HED could be installed in time to realize a positive return on investment. Navy engineers told us that the system cannot be used on newer variants of the DDG 51 class ships without being re-designed.
There are no redundant sources of power when using HED.	The HED motor cannot be used in concert with the main engines. Navy engineers said that if the system stops, the main engines can start up within 2 or 3 minutes if they are positioned during key moments to turn on and accelerate quickly.
The Navy needs to test bi-directional energy and could potentially back fit a motor with these capabilities on DDG 51s to potentially provide improved capability compared to the HEDs.	Navy program officials stated that HED was designed to be bi-directional but that this capability is not supported by the control systems and cannot be activated. Further, while the specific HED unit does not require additional space and weight to operate as a propulsion derived ship service (PDSS) system, other ship upgrades, to include electrical distribution equipment (e.g. cables, switchboards, etc.), that do take up valuable space and weight would be required to complete the bi-directional capability.

Source: GAO assessment of Navy documents and statements. | GAO-21-79R

The Navy did not provide us with information on why it is necessary to suspend the HED program to pursue the PDSS research effort. Further, Navy program officials and engineers told us that they have not determined how the Navy plans to use the five HED systems to advance the PDSS research effort. Navy engineers added that the focus of this research would generally be on how to draw surplus electricity from the propulsion system into the ship's electrical system to power the ship or fire certain weapons. While Navy requirements officials stated that research into PDSS is necessary for supporting future weapon systems, they could not provide any documentation that illustrated the specific benefits of using the existing HED systems to aid in the PDSS research effort.

The June 2020 Senate report asked the Navy to provide a report that includes information on the funding requirements, operational suitability, and effectiveness of the HED system. Completing the testing, cost, benefits, and performance assessments and reporting the results to Congress, as directed in the June 2020 Senate report, could provide the information necessary to make an informed decision about the future of the HED program.

Agency Comments

We provided a draft of this report to DOD and the Navy for review and comment. We incorporated the Navy's technical comments as appropriate.

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

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or oakleys@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Staff making key contributions to this report were Diana Moldafsky, Assistant Director; Laurier Fish, Analyst-in-Charge; Stephanie Gustafson; Jeff Hartnett; William Reed; Lori Fields; and Anne Louise Taylor. Brian Bothwell and Lorraine Ettaro also contributed to this report.

Sincerely yours,

Shelby S. Oakley
Director, CNSA

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