HYPERSONIC WEAPONS

DOD Could Reduce Cost and Schedule Risks by Following Leading Practices

Report to Congressional Committees

July 2024
GAO-24-106792
United States Government Accountability Office

Accessible Version

GAO Highlights

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Highlights of GAO-24-106792, a report to congressional committees
July 2024

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Why GAO Did This Study

Offensive hypersonic weapons move at least five times the speed of sound and have unpredictable flight paths. DOD has begun multiple efforts to develop offensive hypersonic weapons that can be launched on the ground, in the air, and at sea. High costs and failed tests are a concern for some of these efforts.

A joint explanatory statement includes a provision for GAO to review DOD's efforts to develop offensive hypersonic weapons. This report addresses the extent to which DOD's hypersonic efforts are: (1) employing leading practices for product development, (2) identifying and analyzing cost risks, and (3) implementing effective enterprise risk management, among other objectives.

GAO reviewed documentation for the six hypersonic efforts currently being developed by the Army, Air Force and Navy, and interviewed DOD officials.

GAO assessed these efforts using its leading practices for product development, cost estimating, and risk management, as appropriate.

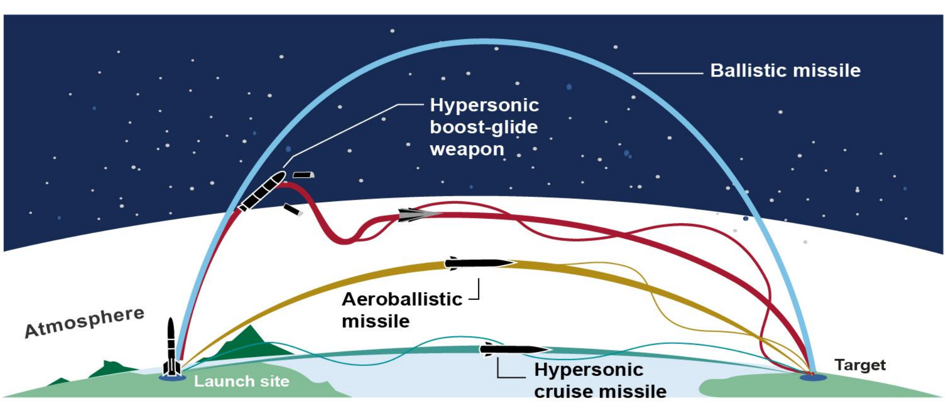
What GAO Recommends

GAO is making 10 recommendations to DOD, including increasing the incorporation of feedback from users into system designs, expanding the use of modern digital engineering tools, improving the Conventional Prompt Strike cost estimate, and expanding enterprise-level reporting activities. DOD concurred with these recommendations.

What GAO Found

The Department of Defense (DOD) is increasingly investing in the development of hypersonic weapons. These weapons' unique characteristics—such as the ability to maneuver at very high speeds—could allow the U.S. to strike heavily defended targets from a distance.

Comparison of Ballistic and Hypersonic Missile Trajectories



Source: GAO analysis of Department of Defense data. | GAO-24-106792

All six offensive hypersonic weapon efforts GAO identified have placed a high priority on delivering quickly, with all intending to deliver a “minimum viable product”—one with the initial capabilities needed for users to recognize value. Four of the efforts, however, are not soliciting user feedback to determine what capabilities to include in their minimum viable product, a leading practice for product development identified by GAO in July 2023.

In addition, four efforts have not adopted leading practices for using digital engineering tools, another leading practice for product development. These tools include virtual representations of physical products. Employing modern digital engineering tools and directly soliciting user feedback both have the potential to speed up the design process, reduce costs, and develop a more usable product.

While DOD has identified and analyzed cost risks, the cost of these weapons is difficult to estimate. This is in part due to DOD’s limited experience developing and fielding hypersonic weapons. For example, the Navy’s estimate for Conventional Prompt Strike—among the most mature cost estimates available—compensates for the lack of quality historical data by relying heavily on the views of subject matter experts. Expert views are best used sparingly, as they can be prone to bias, unless estimators analyze and account for that bias. Addressing this and other issues in accordance with GAO leading practices for cost estimates could provide Navy decision-makers a more accurate estimate.

DOD implemented most elements of an effective risk management framework, which allows agencies to assess and monitor threats to achieving their goals. DOD is not, however, comprehensively reporting to Congress about progress against DOD-wide risks to fielding hypersonic systems. Reporting this information at an enterprise level provides a more complete picture of DOD’s efforts and progress, while promoting transparency.

Contents

Abbreviations

ARRW	Air-launched Rapid Response Weapon
CPS	Conventional Prompt Strike
DOD	Department of Defense
HACM	Hypersonic Attack Cruise Missile
HALO	Hypersonic Air-Launched Offensive anti-surface warfare
LRHW	Long-Range Hypersonic Weapon
MTA	middle tier of acquisition
OD	outcome determination
Q	quarter
SM-6	Standard Missile 6
TBD	to be determined

U.S. GOVERNMENT ACCOUNTABILITY OFFICE

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July 29, 2024

Congressional Committees,

Hypersonic weapons, which move at least five times the speed of sound and have unpredictable flight paths, could allow the United States to strike valuable, heavily defended targets from a distance in the early phases of a conflict. Department of Defense (DOD) research into these weapons dates back decades, but these research efforts did not culminate in the fielding of new systems. However, DOD has now made a variety of investments to develop operational, offensive hypersonic weapons, in part due to the continued growth of anti-access and area denial capabilities by potential adversaries.

Explanatory materials accompanying the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023 include a provision for GAO to review DOD's efforts to develop offensive hypersonic weapons.[1] This report addresses (1) the acquisition approaches DOD is using for offensive hypersonic weapons, (2) the extent to which DOD is employing leading practices for product development to address risks associated with these weapons, (3) the extent to which DOD has identified and analyzed cost risks for these weapons, and (4) the extent to which DOD is managing enterprise-level risks for the development of hypersonic systems.

For the purposes of this report, we defined an offensive hypersonic weapon as a system that (a) travels at speeds in excess of Mach 5, (b) spends a majority of its flight path inside the atmosphere, (c) is capable of maneuvering in flight, and (d) is intended to provide an operational strike capability. Applying these criteria, we identified six offensive hypersonic weapons efforts.

For all our objectives, we reviewed documentation, such as acquisition strategies, and interviewed officials from the Army, Navy, and Air Force, as well as other DOD stakeholders. For the first objective we used this information to provide descriptions of the offensive hypersonic weapons programs and to determine their acquisition pathways and activities. To assess whether DOD is employing leading practices for product development, we reviewed program documentation that addressed schedules, technology issues, and requirements, and compared this information with our leading practices for product development. We focused on practices related to the development of a minimum viable product, as we found these were most applicable given the efforts' stage of development. Specifically, we assessed whether the efforts prioritized schedule by off-ramping capabilities when necessary, directly solicited and incorporated user feedback to inform the minimum viable product, and used digital engineering tools, such as digital twinning.[2]

To assess cost risks, we interviewed cost estimators and reviewed related documentation. We assessed the most recent cost estimate created by the Conventional Prompt Strike effort — which was among the most advanced of the efforts we reviewed and approaching a major acquisition decision — based on our leading

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[1]168 Cong. Rec. H9425, H9648 (Dec 8, 2022) to accompany the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023.

[2]GAO, *Leading Practices: Iterative Cycles Enable Rapid Delivery of Complex, Innovative Products*, GAO-23-106222 (Washington, D.C.: July 27, 2023); and *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles*, GAO-22-104513 (Washington, D.C.: Mar. 10, 2022).

practices for the "accurate" characteristic of a quality cost estimate.[3] To assess enterprise-level risks for the development of hypersonic systems, we interviewed DOD officials who focused on these risk areas, reviewed relevant documentation, and compared these findings with our leading practices for managing enterprise risks.[4] For additional details on our objectives, scope, and methodology, see appendix I.

We conducted this performance audit from April 2023 to July 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

Hypersonic Weapons

The technical and operational concepts that underpin hypersonic weapons are not new. DOD explored various concepts for hypersonic flight from the 1950s to the 1980s, but none of these concepts resulted in an operational capability. Between 2001 and 2014, the U.S. government developed and tested several experimental hypersonic vehicles with a mix of success and failure, including the Hypersonic Technology Vehicle, the Advanced Hypersonic Weapon, and the X-43 test vehicle.

U.S. Strategic Command has had a requirement for a high-speed, long-range, conventional strike weapon since the early 2000s. Efforts to develop hypersonic weapons accelerated starting in 2018 and 2019, in response to potential adversaries such as China and Russia continuing to improve their anti-access and area denial capabilities. Hypersonic weapons are one possible means to counter these capabilities.

High-level DOD strategy documents have articulated DOD's commitment to hypersonic technologies. For example, the 2022 National Defense Strategy identified hypersonic weapons as one capability that will contribute to DOD's strategy and identified it as one of the technology areas in which the United States would seek to build an enduring advantage.[5] In 2022, the Under Secretary of Defense for Research and Engineering identified hypersonic technologies as one of 14 critical technology areas that would guide DOD's investments.[6]

As a result of identifying hypersonic technologies as a top priority, DOD established a Principal Director for Hypersonics within the Office of the Under Secretary of Defense for Research and Engineering. The role of the Principal Director is to establish a plan for hypersonic technology development and act as a coordinator for

[3]GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs,* GAO-20-195G (Washington, D.C.: Mar. 12, 2020).

[4]GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, GAO-17-63 (Washington, D.C.: Dec. 1, 2016).

[5]Department of Defense, *2022 National Defense Strategy* (Washington, D.C.: Oct. 27, 2022).

[6]Department of Defense, Under Secretary of Defense for Research and Engineering, *USD(R&E) Technology Vision for an Era of Competition* (Washington, D.C.: Feb. 1, 2022).

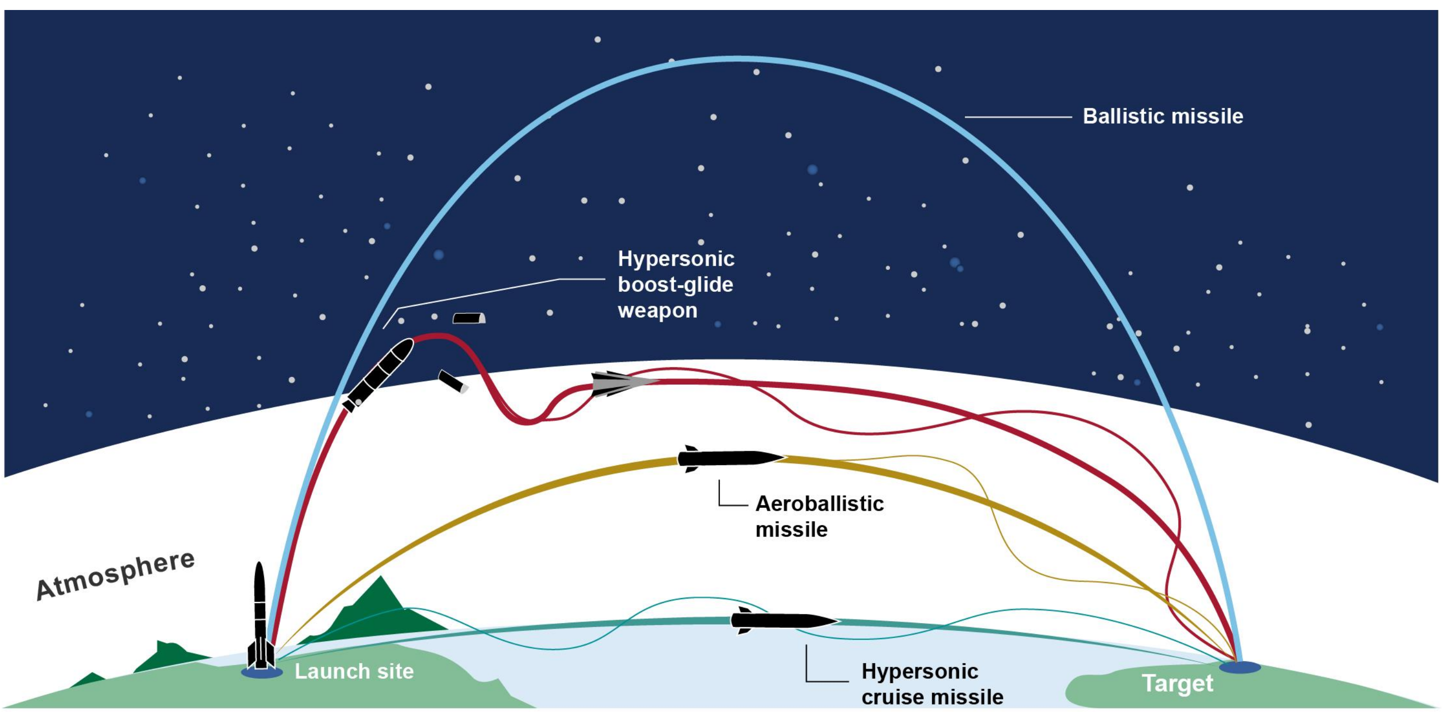
these efforts across DOD. While the Principal Director serves as a coordinator, the military departments remain the primary developers of offensive hypersonic weapon systems.

There are multiple approaches to developing hypersonic weapons.

- Hypersonic cruise missiles work by using a rocket motor to boost the missile to supersonic speeds before switching to a special type of engine known as a scramjet. The scramjet combines supersonic airflow with fuel, which it then ignites to produce thrust.
- Boost-glide systems work by using a missile to propel a payload to the edge of space at which point a glide body separates from the missile and, using aerodynamic lift to extend its range, maneuvers itself toward the target.
- Aeroballistic missiles represent an additional approach to achieving hypersonic speeds. This design is rocket-powered and combines aspects of ballistic and aerodynamic flight. While it does not adhere to a boost-glide trajectory, it still travels at hypersonic speeds and maneuvers within the atmosphere.

Figure 1 provides a comparison of the flight paths of some hypersonic weapon types as well as ballistic weapons.

Figure 1: Comparison of Ballistic and Hypersonic Flight Paths



Source: GAO analysis of Department of Defense data. | GAO-24-106792

Note: Figure not drawn to scale.

We previously reported on several challenges in developing hypersonic weapons.[7] For example, the high-temperature environment around a hypersonic system in flight presents complex physical and chemical challenges that are typically not encountered in other weapon systems. To compensate, offensive hypersonic weapons need specialized components to achieve sustained maneuvering during high-speed flight. The technologies used to deal with these challenges have effects on the system's capability, cost, and manufacturability. In addition, developing and manufacturing offensive hypersonic weapon systems requires a workforce with specialized knowledge.

Finally, developing hypersonic systems requires several types of specialized test facilities. Wind tunnels are used to obtain aerodynamic data for hypersonic vehicles. Arc-heated facilities test material performance at high temperatures. Test tracks and arenas provide data on the lethality of a weapon system. Flight tests are also needed to expose technologies and systems to realistic environments. Flight tests, conducted at flight test ranges, are difficult and expensive to conduct, partly because of the long distances involved and the need to place sensors along that distance to collect test data.

DOD Acquisition Pathways

In January 2020, DOD established the Adaptive Acquisition Framework.[8] The framework emphasizes several principles that include simplifying acquisition policy, tailoring acquisition approaches, and conducting data-driven analysis. The Adaptive Acquisition Framework contains six acquisition pathways. The two that are most relevant for this report are:

- Major capability acquisition: This pathway leads major defense acquisition programs, major systems, and other complex acquisitions through phases, such as technology development, system development, and production, separated by major reviews known as milestone decisions. Programs on this pathway generate knowledge through structured analysis.
- Middle tier of acquisition (MTA): This pathway includes two expedited paths. The first path, rapid prototyping, is intended to quickly develop and demonstrate a capability in an operational environment within 5 years. Rapid prototyping also results in prototypes that a military department can field to the warfighter as an interim capability. The second path, rapid fielding, is intended to begin production of a new or upgraded capability within 6 months, and complete fielding of that capability within 5 years.[9]

[7]GAO, *Hypersonic Weapons: DOD Should Clarify Roles and Responsibilities to Ensure Coordination across Development Efforts*, GAO-21-378 (Washington, D.C.: Mar. 22, 2021).

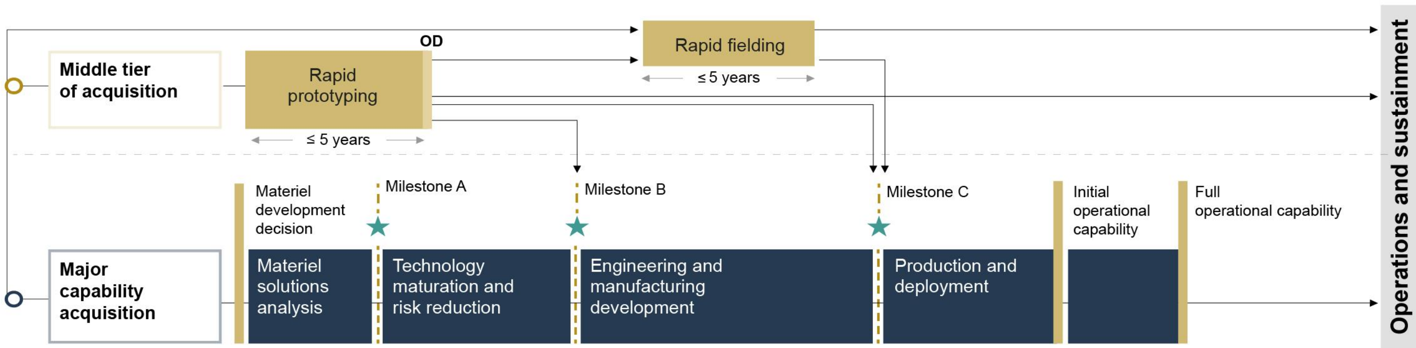
[8]Department of Defense, The Defense Acquisition System, DOD Directive 5000.01 (July 28, 2022); and Operation of the Adaptive Acquisition Framework, DOD Instruction 5000.02 (Jan. 23, 2020). For more information on how DOD is using the Adaptive Acquisition Framework, see GAO, *Weapon Systems Annual Assessment: Challenges to Fielding Capabilities Faster Persist*, GAO-22-105230 (Washington, D.C.: June 8, 2022).

[9] For programs using the MTA pathway, the program start date (and thus the date from which the 5-year timeframe is measured) for programs designated on or after December 30, 2019, is generally the date that the program was designated, which is the date that an acquisition decision memorandum was signed initiating an MTA rapid prototyping or rapid fielding program. MTA programs designated before December 30, 2019, and certain programs designated after this date, generally maintain their MTA program start date as the date funds were first obligated.

Each pathway has requirements for reviews, cost and schedule goals, and reporting to decisionmakers. Acquisitions using the MTA pathway are generally not subject to the same acquisition and requirements processes as those on the major capability acquisition pathway.

The military departments can also transition efforts from one pathway to another. For example, DOD's MTA policy states that military departments will develop a process for transitioning successful prototypes from the rapid prototyping pathway to new or existing programs for production, fielding, and operations and sustainment under the rapid fielding pathway or another acquisition pathway.[10] In addition, the military departments could choose to terminate a program that has not progressed as expected. Figure 2 shows the major capability acquisition and MTA pathways.

Figure 2: Selected Department of Defense Adaptive Acquisition Framework Pathways



OD = Outcome determination

Source: GAO analysis of Department of Defense (DOD) data. I GAO-24-106792

GAO Leading Practices

We have identified leading practices relating to the effective management and oversight of government programs and acquisitions.

Our **leading practices for product development** identify several practices used by leading companies to develop complex, innovative products. Leading companies employ an iterative process when developing complex products. The iterative process involves a continuous cycle, through which companies rapidly develop and deploy products. This process prioritizes schedule by focusing on the development of a minimum viable product—one with the initial capabilities needed for users to recognize value. Three practices are key for developing and improving a minimum viable product:

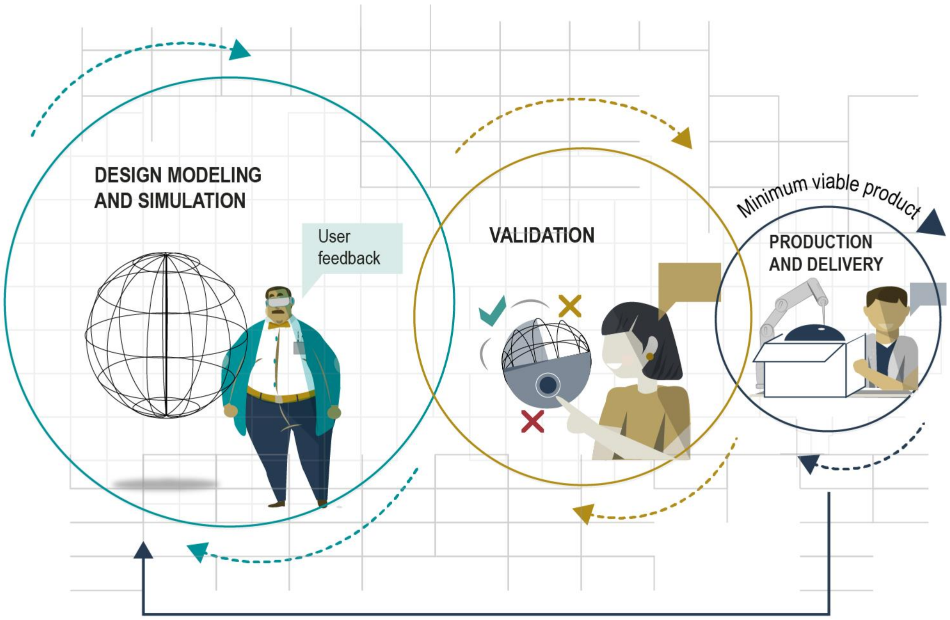
- Leading companies prioritize schedule by off-ramping capabilities when necessary. To achieve speed to market, these companies will prioritize developing a minimum viable product by removing capabilities that pose a risk to delivering the product on schedule. The off-ramped capabilities can be deferred to a later release or terminated.

[10]Department of Defense, Operation of the Middle Tier of Acquisition, DOD Instruction 5000.80 (Dec. 30, 2019).

- Leading companies seek and obtain continuous user feedback—feedback from the actual operators of the product—throughout the iterative cycles. These companies capture this feedback to determine the minimum viable product and to inform improvements to the minimum viable product.
- Leading companies also use digital engineering tools, including digital twins—virtual representations of physical products. Digital twins incorporate dynamic data of a physical object or a system—meaning the model changes and updates in real-time as new information becomes available. Digital twins differ from 3D models, which are static visualizations that are updated manually, and are essentially paper design drawings in digital form.[11]

Figure 3 illustrates the relationships between the different phases of the iterative design cycle.

Figure 3: Leading Companies Progress through Iterative Design, Validation, and Production Cycles to Develop a Minimum Viable Product



Source: GAO analysis of leading company information; GAO (illustration). | GAO-24-106792

Our *Cost Estimating and Assessment Guide*, states that reliable cost estimates must among other things, be "accurate". We define the characteristic of accurate as:

- using the best methodology from the data available,
- properly adjusting for inflation,
- validating underlying formulas and inputs, with the resulting estimate containing few, if any, minor mathematical mistakes,
- regularly updating the estimate to ensure it reflects program changes and actual costs,
- documenting and explaining variances between estimated and actual costs, and

[11]GAO-23-106222; and GAO-22-104513.

- being based, to the extent possible, on a historical record of cost estimating and actual experiences from other comparable programs.[12]

Enterprise risk management describes a forward-looking management approach that allows agencies to assess risks (that is, both threats and opportunities) that could affect the achievement of their goals. This approach employs six elements, including:

- align process to goals and objectives,
- identify risks,
- assess risks,
- select risk response,
- monitor risks, and
- communicate and report on risks.[13]

Figure 4 below illustrates the elements of the enterprise risk management framework.

Figure 4: Essential Elements of Enterprise Risk Management

Source: GAO. | GAO-24-106792

Acquisition Approaches for Hypersonic Weapons Emphasize Rapid Development

Each of the six offensive hypersonic weapons efforts we identified follow an acquisition strategy that places a high priority on quickly delivering capabilities. The efforts' plans for achieving this differ and progress for some efforts have been delayed due to the need to correct issues identified during initial flight testing. Table 1 provides some details on the six offensive hypersonic weapon efforts.

[12] GAO-20-195G. The *Cost Estimating and Assessment Guide* also articulates three other characteristics of a reliable cost estimate: comprehensive (meaning it reflects the current schedule and technical baselines), well-documented (meaning all parts can easily be repeated or updated and can be traced to original sources), and credible (meaning it discusses and documents any limitations, including the possibility of uncertainty or bias). We chose to focus on the accurate element because it was most relevant to the scope of this report.

[13] GAO-17-63

Table 1: Acquisition Approaches of Offensive Hypersonic Weapon Efforts

Weapon	Military department	Initiation date	Expected fielding date (quarter and fiscal year)	Current acquisition pathway	Type	Platform
Long-Range Hypersonic Weapon	Army	August 2019	4Q 2024	MTA rapid fielding	Boost-glide	Truck-based launcher
Conventional Prompt Strike	Navy	October 2019	4Q 2025	MTA rapid prototyping	Boost-glide	*Zumwalt-class* surface ships and *Virginia-class* submarines
Air-launched Rapid Response Weapon	Air Force	August 2018	To be determined	MTA rapid prototyping	Boost-glide	B-52 bomber aircraft
Hypersonic Attack Cruise Missile	Air Force	September 2022	2Q 2027	MTA rapid prototyping	Hypersonic cruise missile	F-15E fighter aircraft
Hypersonic Air-Launched Offensive anti-surface warfare	Navy	March 2023	2029	MTA rapid prototyping	To be determined	F/A-18 (E/F) fighter aircraft
Standard Missile-6 Block IB	Navy	March 2018	4Q 2029	Major Capability Acquisition	Aeroballistic missile	Surface ships

MTA = middle tier of acquisition
Q = Quarter

Source: GAO analysis of DOD documentation. | GAO-24-106792

Note: For the purposes of this report, we use “initiation” to refer to the MTA effort’s start date. For programs using the MTA pathway, the program start date for programs designated on or after December 30, 2019, is generally the date that the program was designated, which is the date that an acquisition decision memorandum was signed initiating an MTA rapid prototyping or rapid fielding program. MTA programs designated before December 30, 2019, and certain programs designated after this date, generally maintain their MTA program start date as the date funds were first obligated.

All the efforts we assessed eventually intend to use the major capability acquisition pathway should they continue to production but differ in terms of what stage they will enter it. Alternatively, decision makers may choose to terminate an effort if it does not develop as expected.

Long-Range Hypersonic Weapon

The Long-Range Hypersonic Weapon effort seeks to deliver a truck-based long-range missile system capable of launching a hypersonic payload, known as the Common Hypersonic Glide Body, on a boost-glide trajectory.

Source: U.S. Army. | GAO-24-106792

Long-Range Hypersonic Weapon (LRHW). The LRHW effort began in 2019 under the Army Rapid Capabilities and Critical Technologies Office's accelerated prototyping authority.[14] The Army delivered the first LRHW battery in 2021, albeit without missiles. A battery is composed of one operations center and four transporter-erector-launchers. Each transporter-erector-launcher consists of a truck and trailer, which carry a launcher that raises to a near-vertical orientation to launch the missile. According to DOD officials, since the first battery was delivered, soldiers have been familiarizing themselves with the launchers and offering feedback. To procure and field the second and third batteries, the Army initiated an MTA rapid fielding effort for LRHW in August 2023, managed by the Army Program Executive Office for Missiles and Space.

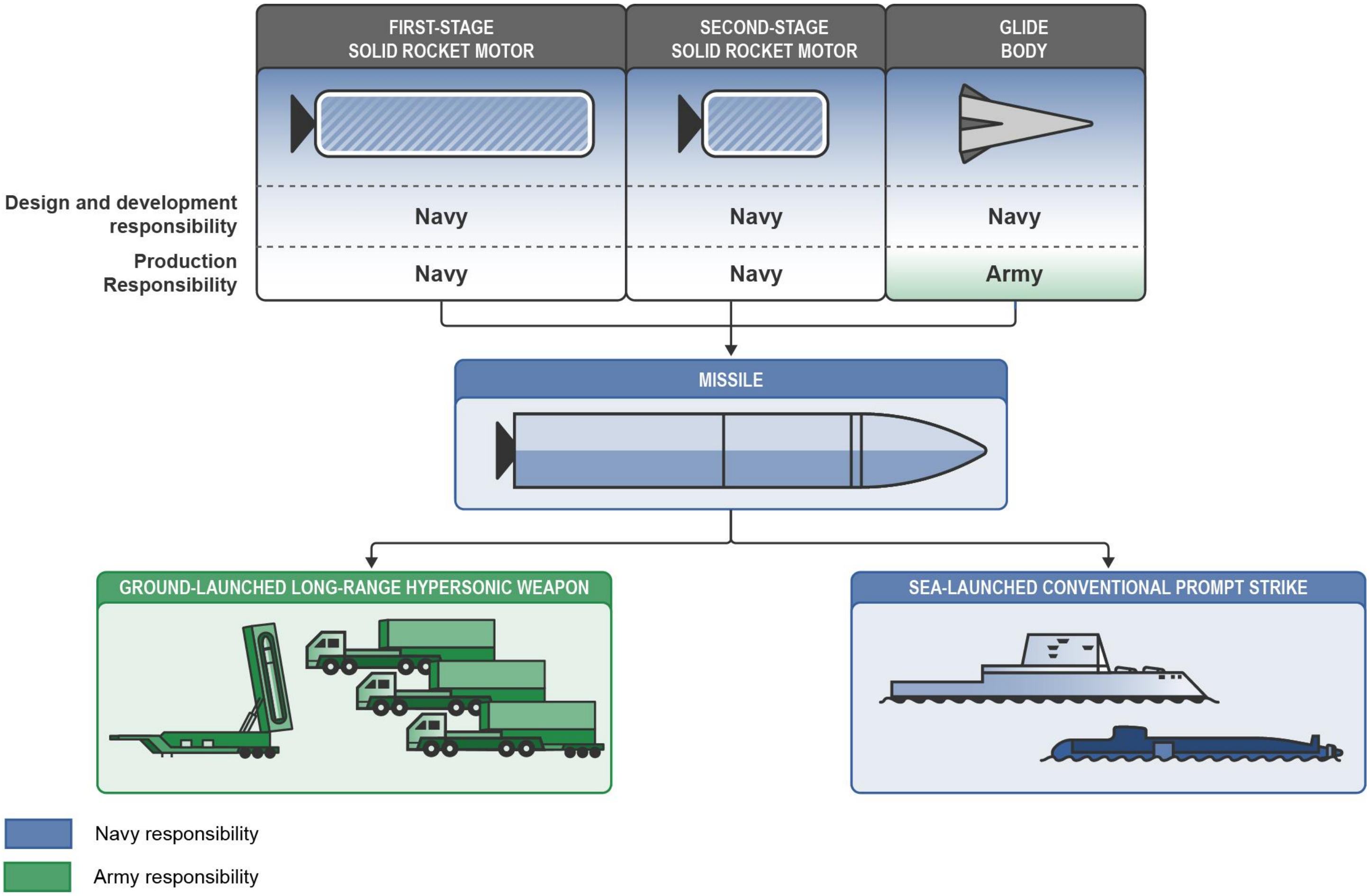
The Army delayed delivery—planned for fiscal year 2023—to at least late fiscal year 2024 due to difficulties discovered in flight testing. During the first flight test in June 2022, the missile launched but failed mid-flight. The next three flight tests failed during the initial launch sequence. According to program officials, integration issues between the launcher and missile caused the test failures. As a result, the Army is conducting a risk review before conducting any further tests. The Army has also paused production of LRHW missiles and does not intend to resume it until the review is complete and there has been a successful flight test of the missile.

According to officials, once the effort conducts a successful flight test, the first missile configured for operational use can be delivered in 6 weeks, with an 11-month timeline to complete all eight such missiles needed for Battery 1. A successful flight test is also required before the Army will declare the system operational. Officials said that the earliest date such a test could occur is the fourth quarter of fiscal year 2024.

LRHW is closely aligned with the Navy's Conventional Prompt Strike (CPS) effort as both use the same missile. The Army procures the hypersonic missile and associated canister through the Navy's CPS effort, while design and production responsibilities for certain subsystems are divided between the Army and Navy. Figure 5 shows this division of responsibilities.

[14]According to the Army, the Rapid Capabilities and Critical Technologies Office's charter at the time permitted it to initiate such projects on its own authority without using the middle tier of acquisition rapid prototyping pathway. Though not a formal middle tier of acquisition effort, the LRHW effort's acquisition strategy still generally resembled a rapid prototyping effort, with a 5-year timeframe, and plans to demonstrate the capability while also creating a residual or limited operational capability at the conclusion of the effort.

Figure 5: Long-Range Hypersonic Weapon and Conventional Prompt Strike Service Responsibilities



Source: GAO analysis of Department of Defense and contractor information. | GAO-24-106792

Note: Figure not drawn to scale.

Conventional Prompt Strike

The Conventional Prompt Strike effort seeks to deliver a long-range missile system capable of launching the same missile used in The Long-Range Hypersonic Weapon effort from surface ships and submarines.

Source: U.S. Navy. | GAO-24-106792

Conventional Prompt Strike (CPS). The Navy initiated the CPS effort in 2019 as a rapid prototyping effort with an initial phase focused on the development of the missiles for use by both the Navy and Army. The Navy plans to field the CPS system on *Zumwalt-class* destroyers starting in the mid-2020s, and on *Virginia-class* submarines in the early 2030s.

The same test failures that delayed LRHW have also delayed CPS. CPS officials adjusted their testing plan in response to the flight test challenges, creating multiple incremental test events prior to the next flight test.

CPS officials plan to initiate a parallel MTA rapid fielding effort after conducting a successful flight test. The rapid fielding effort will focus on integrating CPS onto the first *Zumwalt-class* surface ship. The overall CPS effort will then later transition to the major capability acquisition pathway at low-rate initial production for fielding on *Virginia-class* submarines and the remaining *Zumwalt-class* ships, if testing is successful. For both classes of vessels, the Navy is developing a cold-gas eject system that will be used to conduct the initial launch of the missile before the rocket motors ignite. According to officials, this technology has been previously used by the Navy for submarines, but fielding on the *Zumwalt-class* will be a first for the surface fleet.

Air-launched Rapid Response Weapon

The Air-launched Rapid Response Weapon effort seeks to develop a boost-glide air-to-surface capability launched from a B-52 bomber aircraft.

Source: U.S. Air Force. | GAO-24-106792

Air-launched Rapid Response Weapon (ARRW). The Air Force initiated the ARRW effort in 2018 as an MTA rapid prototyping effort. This effort built on the Defense Advanced Research Project Agency's Tactical Boost-Glide demonstrator, combining it with a new operational rocket motor.

Flight test results for the ARRW effort were initially mixed. The first flight test in late 2022 was successful but gathered limited data. The second flight test in early 2023 failed due to faults with the missile shroud and heat shielding. The effort conducted two additional flight tests in September and October 2023. The need for additional tests delayed ARRW and required Air Force officials to apply for and receive a waiver to the 5-year time frame on rapid prototyping efforts. The waiver extended the effort by one year into 2024 to allow completion of the remaining flight tests. The Air Force plans to conduct a final test in March 2024.

Currently, ARRW and Air Force officials have not decided on plans for transitioning to a new pathway at the conclusion of the rapid prototyping and testing phase. According to officials, the Air Force will review the effort and make decisions on its future in 2024 after the last flight test. There is currently no planned funding for future phases of development or procurement for ARRW in DOD's budget.

Hypersonic Attack Cruise Missile

The Hypersonic Attack Cruise Missile effort seeks to develop an air-launched hypersonic cruise missile for use with the F-15E fighter aircraft.

Source: U.S. Air Force. | GAO-24-106792

Hypersonic Attack Cruise Missile (HACM). HACM effort builds on the Defense Advanced Research Project Agency's Hypersonic Air-breathing Weapon Concept, a scramjet demonstrator. According to HACM officials, the effort evaluated and selected the most technically mature design from the demonstrator program and used it as the basis for HACM's scramjet. In addition to the scramjet, officials said the Air Force will also develop a new solid fueled rocket motor, a section to connect the scramjet and rocket, an explosive payload, and guidance systems.

The Air Force initiated HACM as an MTA rapid prototyping effort in 2022. According to officials, the effort is engaging in an incremental development process that seeks to build and demonstrate the systems through a series of increasingly capable configurations, rather than designing for and demonstrating the final configuration from the start. In this process, the effort conducts an incremental critical design review for the initial, basic configuration planned for the first test flight, rather than a full critical design review for a fully capable configuration. Air Force officials plan a full critical design review for the final design in spring 2025. Air Force officials plan to conduct at least one test flight of the final configuration prior to the conclusion of the rapid prototyping effort in 2027. HACM plans to conduct several flight tests for the prototyping effort, both in Australia from Australian Air Force F-18s, and in the United States from F-15Es. HACM officials said that they added more opportunities for flight testing than prior efforts, based on the assumption that some tests might fail.

If the tests are successful, the Air Force plans to transition HACM to the major capability acquisition pathway at either development start or production start in 2027, depending on what capabilities the Air Force is willing to accept and whether production facilities are ready.

Hypersonic Air-Launched Offensive anti-surface warfare

The Hypersonic Air-Launched Offensive anti-surface warfare effort seeks to develop an air-launched hypersonic weapon for the Navy's F-18 E/F fighter aircraft.

Source: U.S. Navy. | GAO-24-106792

Hypersonic Air-Launched Offensive anti-surface warfare (HALO). The HALO effort initiated under the MTA rapid prototyping pathway in March 2023. The Navy placed orders with two contractors with competing designs, according to officials. The Navy intends to take both designs through a preliminary design review, then select a single contractor to continue system development. The HALO effort intends to deliver an initial capability by fiscal year 2029.

HALO officials said that they do not plan to keep the effort within the rapid prototyping pathway through the creation and demonstration of a successful prototype. Instead, officials said that they only plan to stay within this pathway through the conclusion of the current concept development contracts and preliminary design reviews, currently scheduled to conclude in fiscal year 2025. At that point, the effort plans to transition to the major capability acquisition pathway at system development.

Standard Missile 6 Block IB

The Standard Missile 6 (SM-6) Block IB is the latest upgrade to the Navy's existing SM-6 family currently fired from surface ships. According to SM-6 Block IB officials, the upgrade would increase the range, speed, and capability of the missile by replacing the current second stage rocket motor with a larger, more powerful one capable of achieving hypersonic speeds.

Source: U.S. Navy. | GAO-24-106792

Standard Missile 6 (SM-6) Block IB. The Navy initiated the SM-6 Block IB effort in 2018 with an MTA rapid prototyping effort to develop the new, more capable second-stage rocket motor, designed by the Navy. The Navy planned to follow this with a second rapid prototyping effort to incorporate the new motor into an improved SM-6 missile.

While developing the new rocket motor, Navy officials discovered that an additional upgrade to the entire SM-6 family was required due to a component obsolescence issue. According to officials, the approach the effort took to upgrading the second stage rocket motor was not feasible. As a result, the Navy ended the prototyping effort and transitioned the SM-6 Block IB to a major capability acquisition pathway in 2021. The Navy has awarded two other transaction agreements to industry for the second stage rocket motor, with plans to later select a single design. As of September 2023, Navy officials said the program office has identified dates to meet certain milestones, however these dates are subject to change.

Hypersonic Efforts Are Not Fully Implementing Leading Practices for Product Development

DOD's hypersonic weapon development efforts are not fully implementing leading practices for product development, which we have found enable leading commercial companies to deliver products quickly. For example, the efforts are determining which desired capabilities are most essential and achievable and intend to develop a minimum viable product that the military departments can then deliver quickly to the warfighter. Not all the efforts, however, are soliciting user feedback to determine which capabilities to include in the minimum viable product or to inform future iterations of the design. In addition, some efforts have yet to fully adopt the use of advanced digital engineering and digital twins.

Trade-offs to Facilitate Rapid Development Do Not Fully Incorporate User Feedback

Our leading practices for product development identify the ability of programs to cancel or defer certain capabilities as critical to on-time delivery of a minimum viable product. Leading companies then improve the minimum viable product through iterative development—the successive incorporation of new capabilities over time.[15]

All six efforts we reviewed have taken steps consistent with this approach or plan to do so:

- LRHW demonstrated this approach when dealing with an issue with achieving one of the desired capabilities identified by the Army: the ability to transport the missile by rail. During system development, Army officials determined that they would have to re-design the missile launcher to transport it by rail. LRHW had already demonstrated transportability by aircraft, and according to officials, air-transportability was considered the more important capability. Army officials decided to defer meeting the rail-transportability capability to maintain schedule, as it was not necessary for a minimum viable product. Figure 6 shows LRHW on an aircraft for transport.

Figure 6: Demonstration of Air Transportability of Long-Range Hypersonic Weapon

Source: U.S. Army. | GAO-24-106792

- CPS delayed the integration of an advanced capability into its initial design. While the Navy desires this capability, officials told us that they understood early in development that achieving it would take considerable time and effort. Therefore, they deferred this capability in favor of developing a minimal viable product that the effort can quickly field to the warfighter. Officials stated that CPS is leveraging an incremental approach to add other additional capabilities in future iterations.

- ARRW identified technologies whose inclusion would have delayed the delivery of the product beyond the 5-year rapid prototyping time frame. The effort deferred those technologies for inclusion in a future increment, should funding for that increment become available.

[15]GAO-23-106222

The HACM, HALO, and SM-6 Block IB efforts are also employing a minimum viable product approach, but given their current phase of development there have been fewer opportunities to make similar decisions regarding specific capabilities.

- HACM officials affirmed that they intend to refine the minimum set of capabilities to be included in the minimum viable product and are adopting software architectures that can facilitate future updates.
- HALO's acquisition strategy states that the effort will culminate with a demonstration of a minimum viable product that meets the range and speed requirements to engage a target.
- SM-6 Block IB officials described the current effort as aimed at delivering a minimum viable product. Officials acknowledged that future capabilities could be added through software. They also said that aspects of the acquisition strategy are not finalized and still subject to change.

Our leading practices also state that direct and timely collaboration with users is essential to determining the most essential capabilities for including in the minimum viable product.[16] Importantly, our leading practices state that users are individuals that directly interact with the system, such as operators and maintainers. This does not include high-level officials who may determine requirements, nor other leaders who may make decisions about whether to continue development or to buy a product. While these individuals are important, we have found that leading companies prioritize user needs in defining and iteratively improving their minimum viable product.

Our review of the six offensive hypersonic efforts showed that officials from two efforts—LRHW and CPS—are soliciting and incorporating user feedback or have plans to do so.

- LRHW officials have solicited extensive feedback from operators and maintainers in the design phase. These officials told us the effort fielded the LRHW launcher and other ground equipment to soldiers over 2 years in advance of the official deployment of the system for familiarization and to obtain feedback. This feedback was then used to make changes to the launchers and associated systems. LRHW officials told us the effort intends to obtain additional feedback from soldiers after the delivery of the first battery of missiles. They will then use this feedback to inform iterative development of the system and validate future capabilities for the second and third LRHW batteries.
- According to CPS officials, they have also been soliciting and incorporating user feedback during system development. For example, officials placed a prototype weapon control system and simulated missile on the USS Zumwalt and allowed users to operate the system in a simulated environment. They then collected user feedback on the design, installation, and ability to interface with the ship's systems. Officials further stated that they will continue to solicit and incorporate user feedback during development.

We determined that officials from the remaining four efforts—SM-6 Block IB, HACM, HALO, and ARRW—do not currently solicit and incorporate direct and timely user feedback or have plans to do so in the future. While officials from these efforts are soliciting and collecting feedback from a variety of stakeholders, these stakeholders do not constitute "users" in the sense of individuals who physically interact with or directly operate the system.

[16] GAO-23-106222 and GAO-22-104513.

- SM-6 Block IB officials told us the effort is not soliciting and obtaining feedback directly from users and has no plans to do so. Officials stated that generally their weapon development efforts rely on input from Navy leadership.
- HACM officials do not have plans to directly solicit and incorporate user feedback during the design phase. Officials stated that, while no official channel for doing so is planned, users could provide feedback to their respective requirements officers following testing.
- HALO officials told us they do not have plans for soliciting or incorporating user feedback at this time. Instead, the effort is soliciting feedback from mission planners rather than end users.
- ARRW officials also stated that they did not have plans to obtain direct, timely feedback from end users. According to officials, they have involved maintainers, but their focus was primarily on the development of training orders for maintaining the weapon rather than input on its design or features.

At present, offensive hypersonic weapon efforts are not required to solicit this type of feedback throughout development. We previously reported that DOD's software acquisition policy requires solicitation of feedback from users, but the policies for other acquisitions do not contain a similar requirement. As a result, there is no policy outlining the mechanisms to solicit and incorporate user feedback that extends to all DOD acquisition programs and efforts.

In 2022, we recommended DOD implement incorporating feedback from users of initial capabilities throughout development, but the department has yet to incorporate this into its policies.[17] Such a policy would better position programs and efforts to understand user needs, develop capabilities to meet those needs, and better plan for future iterative development. The absence of such a policy does not preclude efforts from soliciting user feedback, which could help them meet user needs in a timely fashion.

Efforts Are Not Fully Incorporating Other Practices that Could Speed Up Development

Our prior work has found that leading companies benefit from developing a variety of models using digital engineering tools, such as digital twinning, during the design modeling and simulation phase.[18] A digital twin is a virtual model that simulates the configuration, performance, and behavior of a system within a computer. This virtual model can be updated when new features are added. A high-fidelity digital twin, coupled with high-resolution simulations of the operating environment, can be used for testing the system to validate that it meets requirements. This reduces the need to build physical prototypes each time the design changes. In addition, digital twins are also useful in the sustainment phase. These digital design tools are useful in the design and validation process as they can enable more rapid iterative design cycles and facilitate stakeholder and user feedback at earlier stages.

We determined that the HALO and CPS efforts are either currently using digital engineering tools, including digital twins, or have plans to do so in the future. Specifically:

[17]GAO-22-104513. DOD concurred with this recommendation and stated it would consider the integration of key product development principles, to include incorporating user feedback, when it updates its overarching acquisition policy, the individual acquisition pathways, and functional acquisition policies. DOD anticipates completing this effort by June 2024.

[18]GAO-23-106222 and GAO-22-104513.

- HALO's acquisition plan states that the prime contractor will need to establish a digital engineering ecosystem—i.e., a single, integrated computer environment—as well as the use of digital engineering tools. According to HALO officials, vendors are required to provide high-fidelity digital models of the components and subsystems in the design, which DOD officials can then assemble and test as a digital prototype.
- CPS also has a digital engineering plan that includes a transition to a computing environment similar to HALO's. Program officials stated that CPS has used a 3-D model in design, which they have found to be useful in development. Officials plan to use digital engineering tools and techniques in the future to prepare for production and eventual sustainment. According to officials, the challenge with the approach is bringing the various models of the missile and missile components, such as the CHGB, together to create a full digital representation.

Officials from the remaining four efforts—LRHW, SM-6 Block IB, ARRW, and HACM—are either not using digital engineering or are using it only to a limited degree and lack any plans to further implement these tools in the future. Specifically:

- LRHW officials used some digital engineering tools to create a virtual reality model of the launcher that users could interact with to identify potential design flaws. From these interactions, users were able to identify potential maintenance challenges based on the placement of certain components, such as a generator. Officials were then able to make modifications to the digital and physical design, incorporating this feedback. While this simulation is useful for some applications, it is not a high-fidelity, dynamic digital model necessary for implementing digital engineering. LRHW officials said that they do not plan to develop digital models of this kind.
- SM-6 Block IB officials reported they do not plan to use digital engineering tools or digital twins. Instead, they stated they intend to continue to leverage modeling and simulation tools used in previous Standard Missile programs. This falls short of the advanced digital engineering tools our leading practices identified. Program officials acknowledged that effort could leverage a digital twin, but they currently plan to focus their attention on developing underlying technologies for the system without it.
- ARRW officials reported they do not use digital twinning. they stated that they do not have specific plans to increase their use of digital engineering tools beyond the typical use of models and simulations.
- According to HACM officials, they attempted to leverage digital design tools, up to and including fully digital design reviews. They stated, however, that there are challenges to conducting these reviews, including the number of tools in use, licensing restrictions, limited computing power, and the logistics of conducting reviews in a way that is accessible to the large number of Air Force stakeholders. HACM officials are not planning to use a digital twin and will instead continue to use 3D models, which are less dynamic and not as easily updated in real time.

DOD issued a policy in December 2023 requiring efforts initiated after the date of issuance to incorporate digital engineering.[19] The policy also states that existing efforts, such as the offensive hypersonic efforts, may incorporate digital engineering when it is practical, beneficial, and affordable, but are not required to do so under the policy. Our past work highlighted that private companies use digital engineering tools to allow for faster iterative design cycles than what would be possible with physical prototypes alone.[20] While fully utilizing digital engineering tools can pose certain challenges, efforts that do not may be missing opportunities to take

[19]Department of Defense, Digital Engineering, DOD Instruction 5000.97 (Dec. 21, 2023).

[20]GAO-23-106222 and GAO-22-104513.

advantage of the efficiencies they can provide. This includes the ability to anticipate potential design flaws, optimize manufacturing, and reduce costs. A formal, documented assessment of whether and how to implement these tools would better position these efforts to take full advantage of the benefits they can provide.

DOD Has Identified Its Limited Experience with Hypersonic Weapons as a Risk in Accurately Estimating Costs

According to multiple DOD and program officials, DOD's limited experience designing, producing, and testing hypersonic weapons provides a limited basis to determine the cost of prototyping while also complicating efforts to project those costs into the future. We assessed the cost estimate for the CPS effort, one of the more mature estimates among those we identified and found it was affected by these uncertainties. Reducing or otherwise accounting for uncertainties will limit the risk of DOD allocating resources without a full understanding of the costs for its hypersonic weapon efforts. We found that while the estimate meets many of our leading practices for cost estimating, the Navy could improve its cost estimating methodologies and how it updates the estimate to account for actual costs. For example, we found the estimate relied heavily on the input of subject matter experts, whose inputs can be prone to bias unless estimators further analyze and account for that bias.

Limited Experience with Hypersonic Weapons Contributes to Uncertainty over Costs

According to DOD officials and contractor representatives, DOD's limited experience overseeing hypersonic development efforts, particularly those with the range and performance of those systems currently under development, is a key driver for near-term costs, while also complicating efforts to estimate future costs. Program officials noted that, to a large extent, rapid prototyping efforts do not lend themselves to creating affordable designs, as their priority is to demonstrate a capability quickly These designs require additional work in the future to make them easier to produce or to incorporate less expensive materials or processes.

Further, many critical components for hypersonic weapons do not have commercial equivalents, and therefore rely on unique components or materials. In many cases, only one or two vendors may be capable of producing these items, limiting opportunities for competition. Some of these unique items also rely on labor-intensive processes with significant lead times. As DOD and industry gains experience designing, building, and testing hypersonic weapons, officials expect the designs will become easier to manufacture at scale. Until this occurs, however, the full cost of these programs is difficult to estimate with confidence.

Current estimates of unit cost are also a consideration in these procurement decisions. For example, LRHW officials stated that missiles for the second and third batteries are estimated to cost over $40 million each. This results in a total potential cost of over $1.28 billion to fully equip those two batteries with missiles once the launchers and other ground support equipment have been procured.

DOD officials also acknowledged that high unit costs could result in DOD procuring fewer weapons, potentially at levels below those needed to meet a combatant command's operational requirements. At the same time, DOD officials said that military departments have been reluctant to plan and budget for significant quantities until they know which offensive hypersonic weapons will meet warfighters' needs. These uncertainties for production complicate the calculation of costs for any subsequent programs to field these weapons.

Despite these difficulties, most hypersonic weapon efforts have some form of cost estimate, even if it only includes costs associated with the current phase. Table 2 provides key details for these estimates.

Table 2: Details of Hypersonic Weapon Efforts' Cost Estimates

Name	Year conducted	Total (then-year dollars in billions)	Scope
Long-Range Hypersonic Weapon	2023	$10.3	Army lifecycle cost estimate for ground support equipment and missiles
Conventional Prompt Strike	2021	$30.1	Navy lifecycle cost estimate, including development and production
Air-launched Rapid Response Weapon	2019	$1.2	Air Force lifecycle cost estimate for rapid prototyping
Hypersonic Attack Cruise Missile	2022	$1.9	Air Force cost estimate for rapid prototyping
Hypersonic Air-Launched Offensive anti-surface warfare	2023	$1.5	Navy cost estimate for research and development
Standard Missile-6 Block IB	TBD	TBD	No cost estimate available due to program restructuring

TBD = to be determined

Source: GAO analysis of Department of Defense documentation. | GAO-24-106792

Note: This table should not be used for comparison purposes, due to the differences in the scope of the estimates.

CPS Cost Estimate Could Improve Its Methodologies and Better Incorporate Actual Costs

Our analysis of the CPS effort's most recent cost estimate showed that while it substantially met three of the five elements of an accurate cost estimate, it could improve its methodologies to better account for DOD's limited experience with hypersonic weapons and its approach to updating the estimate with actual costs.[21] According to our leading practices, an accurate cost estimate is based on a detailed cost model—a build-up of program costs for each cost element necessary for accomplishing all work and delivering the end product. Validating that a cost estimate is accurate requires thoroughly understanding and investigating how the cost model was constructed.

While most of the offensive hypersonic weapon efforts we assessed have some form of cost estimate, we assessed CPS because it was among the more mature of the six efforts we identified and approaching a decision to enter the rapid fielding phase of the MTA pathway. According to CPS officials, this meant that the estimate was relatively up-to-date, but was still technically in draft form. We assessed the CPS estimate against five leading practices for the accurate characteristic: (1) the methodology used; (2) the adjustments

[21]GAO-20-195G also identifies "Contains few, if any, minor mistakes" as an element of the "accurate" characteristic. The Navy declined to provide to us the full cost model for review due to the draft nature of the estimate. As a result, we did not score this element. Not having the full cost model complicates our ability to determine if all calculations are accurate and account for all costs. Westill reviewed the supplemental documentation provided and solicited information on the CPS effort's quality control process and found few, if any, mistakes. Additionally, we are not providing the total figure in this report because doing so would limit our ability to publicly release the report.

made for inflation; (3) whether it reflected changes made to the program; (4) the treatment of variances in planned and actual costs; and (5) the use of historical records from analogous programs.[22]

Methodology used (partially met). We found that the cost estimate only partially met the requirement that estimators ensure it is based on the best methodology available. Given the unique nature of the CPS effort there are few, if any, direct analogies to offensive hypersonic weapons. To account for this in their methodology, cost estimators leveraged analogous historical data from other missile programs. For example, the cost estimators used the Trident II D-5 program as a point of comparison, making an adjustment based on the different weights of the missiles. However, D-5 outweighs the CPS missile by a considerable factor. According to our leading practices, when choosing analogous programs, the technical parameters compared should be roughly similar to the program for which the estimate is performed. When the technical parameter is as different as the D-5 analogy, the cost adjustment may not reasonably explain the potential cost differences between the programs.

In cases where analogous programs were not available, or deemed not appropriate, we found the estimate relied on the opinion of subject matter experts. The expert opinion method should be considered subjective unless estimators further analyze and account for the assumptions within those experts' opinions. Our leading practices state that expert opinion should be used sparingly, and the estimate should account for the possibility that bias influenced the results. We found that, while the estimate relied heavily on subject matter expertise, the estimate's methodology did not capture the full extent of potential bias in these inputs.

While the estimate accounts for the uncertainty stemming from the limited availability of analogous or actual data by increasing the margins within the estimate, estimators did not employ cross-checks to further account for uncertainties when using historical analogies. Cost estimators apply cross-checks by using alternative estimating methodologies to see if they produce similar results, ensuring greater credibility in the resulting estimate. However, for the CPS cost estimate, the Navy did not document its cross-checks in the model or provide supplemental documentation for crosschecks during our review. When asked about the lack of cross-checks on areas such as the D-5 analogy, CPS cost estimators stated they were not necessary because the element they estimated was a small percentage of the total estimate. While the analogy may only represent a portion of the estimate, our concerns with the lack of cross-checks remain.

Additionally, the estimate used an atypical methodology to update engineering costs based on schedule delays. Rather than updating the entire estimate's assumptions for the time (and thus expense) necessary to complete this engineering, the estimate added a new element to account for them. Because the cost of each element of the estimate is linked to specific schedule assumptions, not performing a global update to the estimate's schedule risks invalidating estimates for other elements of the overall effort. CPS cost estimators stated that they used a new element because it was too burdensome to update the entire model. In addition, they stated that the costs of this specific delay would soon be realized and thus "sunk." Even if these costs are sunk, however, the risk of invalidating other aspects of the model remains.

Adjustments for inflation (substantially met). We found that the Navy substantially met the criteria for properly adjusting for inflation in both its cost model and the inputs for the estimate. Cost estimators used a

[22]GAO-20-195G. Our leading practices also include three other characteristics of a reliable cost estimate: comprehensive (meaning it reflects the current schedule and technical baselines), well-documented (meaning all parts can easily be repeated or updated and can be traced to original sources), and credible (meaning it discusses and documents any limitations, including the possibility of uncertainty or bias). We chose the accurate characteristic for this assessment because it was the most relevant to the scope of this report.

database that provides cost data normalized to a specific base year, and they used a software package that has built-in functions to account for inflation. For the development and production phases, cost estimators used 2023 indexes from the National Reconnaissance Office since they were more applicable to CPS than other Navy indexes.

Updates to reflect program changes and actual costs (partially met). We found that the cost estimate partially met the criteria to update the results of the cost estimate to reflect program changes and actual costs. Navy estimators received cost data from contractors and subcontractors and used these data to update their estimate. However, due to data quality issues with the prime contractor's reports and the unique nature of the first efforts to build the system, cost estimators did not input this information directly into the estimate. Instead, estimators used the actual cost data to cross-check their existing estimate. These crosschecks are not documented in the cost model, however. In addition, as noted above, the estimate accounted for the costs of schedule delays by placing them as a separate entry in the estimate rather than updating the model's schedule and examining its effects across the original estimate. According to our leading practices, not updating the estimate makes it more difficult to analyze changes in program costs and hinders efforts to collect cost and technical data to support future estimates.

Document, explain, and review variances between planned and actual costs (substantially met). We found that the estimate substantially met the criteria for documenting, explaining, and reviewing variances between planned and actual costs. We found that cost estimators kept an estimating change log that documented the changes made within the model as well as the resulting variances between different iterations of the estimate. Estimators demonstrated that costs within the estimate are updated as actual cost data arrive, though not at the most detailed levels of the estimate.

Use of historical records from analogous programs (substantially met). We found that the cost estimate substantially met the criteria for using historical records from analogous programs. As stated previously, DOD does not have significant experience overseeing the development or fielding of hypersonic weapons. As a result, estimators had limited historical data applicable to the effort. In spite of that limitation, we found that the limited historical data sources the Navy used for the CPS cost estimate are applicable to the program. We found that CPS cost estimators tried to draw from a range of missile systems, scaling to the extent possible to the relevant technical parameters. As noted above, the estimate's methodology did not completely account for the disparity between the specifications and requirements of the CPS system and the chosen analogous programs. The system's unique design, however, means that the data used in the CPS estimate are among the best available.[23]

While the cost estimate substantially meets most of our leading practices associated with the accurate characteristic of cost estimating, there are further steps cost estimators could take. CPS cost estimators said that they were aware of these steps and that they did not take them as they would be burdensome to execute on all parts of the estimate. Adjusting the methodology of the estimate and better integrating updated schedule

[23]GAO-20-195G also identifies "Contains few, if any, minor mistakes" as an element of the "accurate" characteristic. Due to the draft nature of the Navy's estimate, we were unable to review the full cost model. As a result, we did not score this element. Not reviewing the full cost model complicates our ability to determine if all calculations are accurate and account for all costs. Westill reviewed the supplemental documentation provided and solicited information on the CPS program's quality control process and found few, if any, mistakes.

assumptions and real-world data could be worth this effort as it will provide Navy decision-makers a more accurate cost estimate and could act as a model to cost estimators for future offensive hypersonic weapons.

DOD Is Not Fully Implementing Enterprise Risk Management for Hypersonic Weapons

In addition to cost risks, DOD has identified a number of challenges and risks at the enterprise level for managing hypersonic weapons. DOD also identified a number of actions intended to address them. These actions implement most of the essential elements of an effective enterprise risk management framework as described in our leading practices.

Enterprise risk management is a forward-looking management approach that allows an agency to assess risks that could prevent the achievement of its goals. In this sense, "risks" can be both threats to achieving goals as well as opportunities identified by the organization as important to meeting its goals. We previously identified six essential elements for an agency to effectively manage risks through this framework.[24] These elements are: (1) aligning the risk management process with the agency's goals and objectives; (2) identifying risks; (3) assessing risks; (4) selecting risk responses; (5) monitoring risks; and (6) communicating and reporting on risks. While DOD is meeting the first five elements, it is inconsistently reporting progress on addressing risks and the costs to do so to Congress.

DOD Is Substantially Identifying, Assessing, Addressing, and Monitoring Risks

DOD completed the first essential element of an enterprise risk management framework, which is to align the risk management process for offensive hypersonic weapons to the agency's goals and objectives. The 2022 National Defense Strategy, which describes the military challenges facing the country and the means to address them, states that DOD will develop hypersonic systems to bolster the military capabilities of the United States.[25] The strategy also states that DOD will support hypersonic research and development as part of building an enduring foundation for future military advantage. Furthermore, the Under Secretary of Defense for Research and Engineering identified hypersonics as one of DOD's 14 critical technology areas in 2022. These areas guide investments to accelerate transitioning key capabilities to the military services and the combatant commands.[26]

The Under Secretary designated a senior DOD official, the Principal Director for Hypersonics, to serve as the focal point to coordinate hypersonic research and engineering activities across the department.[27] The Principal Director is also to lay out a strategy for achieving both the first generation of hypersonic weapons, as well as subsequent generations covering more missions and with expanded capabilities. The activities coordinated by the Principal Director's office include managing enterprise risks that affect the development and fielding of

[24]GAO-17-63.

[25]Department of Defense, *2022 National Defense Strategy of the United States of America Including the 2022 Nuclear Posture Review and the 2022 Missile Defense Review* (Washington, D.C.: Oct. 27, 2022).

[26]Department of Defense, Under Secretary of Defense for Research and Engineering, *USD(R&E) Technology Vision for an Era of Competition* (Washington, D.C.: Feb. 1, 2022); and *National Defense Science and Technology Strategy 2023*.

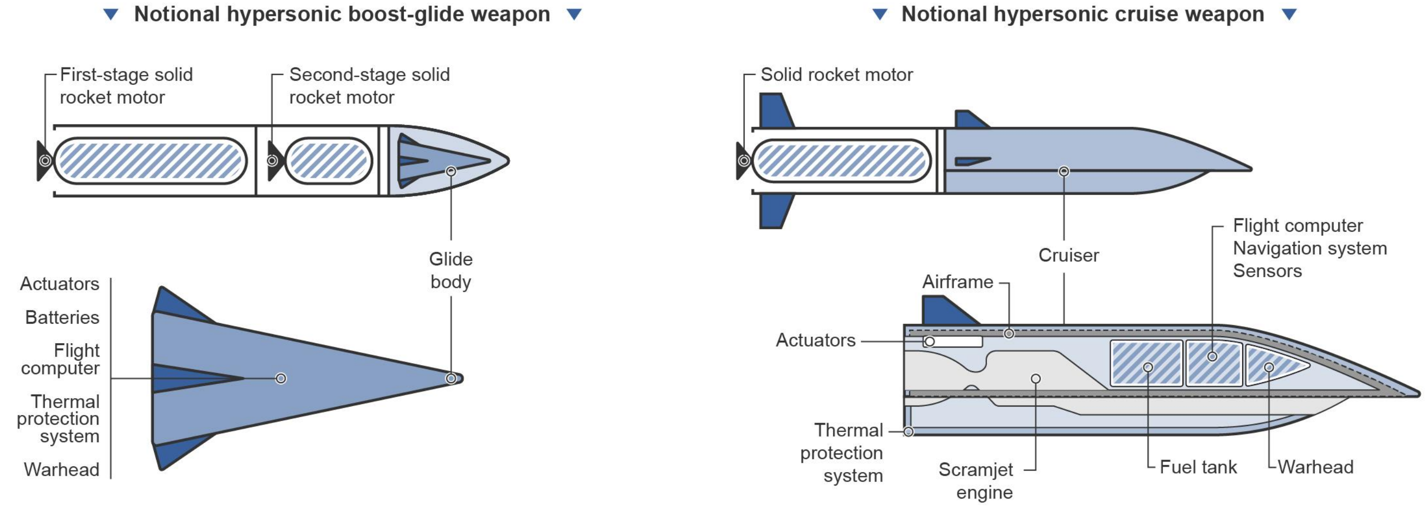
[27]William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283, § 217.

offensive hypersonic weapons. The director coordinates with other offices with responsibilities for elements of hypersonic development, including the Joint Hypersonics Transition Office, Office of Manufacturing Capability Expansion and Investment Prioritization, and Test Resource Management Center.

DOD has substantially implemented the second, third, fourth, and fifth essential elements of an enterprise risk management framework by identifying risks, assessing them, selecting responses to address them, and monitoring them. We categorized these risks and responses into four enterprise-level areas: technology, industrial base, test and evaluation, and workforce. We have previously reported on these risks as well as some of DOD's responses to address them.[28]

Technology. DOD stakeholders in offensive hypersonic weapon efforts have identified technology risks for both present and future systems and assessed their importance. These risks include current technology challenges as well as enabling technologies that, if developed successfully, could increase production rates or provide additional capabilities for future systems. Specific technology risks include materials for thermal protection systems, alternative navigation systems, propulsion systems, and sensors, among others. Figure 7 illustrates components within hypersonic boost-glide and cruise weapons.

Figure 7: Notional Hypersonic Boost-Glide and Hypersonic Cruise Weapons



Source: GAO analysis of Department of Defense and contractor information. | GAO-24-106792

Notes: Actuators are hardware that take command signals and move control surfaces, such as fins, enabling a weapon to maneuver in the atmosphere.

Scramjet engines are propulsion systems that use shock waves to compress incoming oxygen from the atmosphere and slow it to supersonic speeds. The engine then mixes the compressed oxygen with fuel, combusts the mixture, and expels the combusted products from the cruiser to generate thrust.

Warheads are a part of a weapon's payload and contain explosives and other components designed to damage a target.

- Thermal protection systems insulate offensive hypersonic weapon systems against air heated to high temperatures by shock waves and aerodynamic friction, and are a limiting factor for a system's range and maneuverability. These systems are difficult to manufacture and are a cost and schedule driver, according to DOD officials and industry representatives.

[28]GAO-21-378

- Alternative navigation systems maintain the course of offensive hypersonic weapons in contested areas where GPS signals may be jammed or spoofed.[29] Navigation systems need to survive and function in hypersonic flight conditions.
- Propulsion systems include solid rocket motors and scramjet engines. The development of solid rocket motors is a large technical challenge, according to DOD officials, and their production is a cost and schedule driver. While DOD has successfully demonstrated scramjet engines, the demonstration vehicles were not designed to be operational weapons or mass-produced. Furthermore, the scramjet engine is a major cost driver for hypersonic cruise missiles.
- Sensors can increase the capabilities and effectiveness of offensive hypersonic weapons. DOD officials said that additional technology development is needed for sensors to survive and function in hypersonic flight conditions, to integrate them into weapon systems, and to improve their manufacturability.

To address these risks, the Joint Hypersonics Transition Office and other DOD offices prioritize and provide funding for technology investments. They provide funding for multiple areas of hypersonic research at government labs, academia, industry, and federally funded research and development centers. For example, DOD offices reported providing funding for research of alternative materials and manufacturing methods, such as additive manufacturing for scramjet engine components.[30] DOD officials reported providing partial funding for a project to produce carbon-carbon material for thermal protection systems more rapidly using an alternative manufacturing method.[31] The department also provides funding for the maturation of technologies, such as alternative navigation systems and sensors, and their transition into weapon development efforts.

In terms of monitoring, the Joint Hypersonics Transition Office oversees the science and technology projects it funds and whether they transition successfully. For every project, the office assigns a technical manager responsible for oversight and coordination with stakeholders to transition technologies, according to office officials. Officials also said that the office monitors projects by conducting quarterly technical and programmatic reviews to validate performance measures related to schedule and budget as well as deliverables to an assigned transition partner. The office briefs the Principal Director for Hypersonics on the progress and transition status of its projects on a quarterly basis. The office is working with the Principal Director and other stakeholders to revise its hypersonic science and technology roadmap and align the community's investments based on the capabilities needed for DOD's hypersonic weapon systems.

Industrial base. DOD, through multiple studies, has identified and assessed risks with the industrial base that affect the manufacturing and cost of offensive hypersonic weapons and can impede increased and affordable production. Specific risks include those listed below.

[29]We have previously reported on DOD's efforts to develop positioning, navigation, and timing technologies to complement GPS. GAO, *Defense Navigation Capabilities: DOD Is Developing Positioning, Navigation, and Timing Technologies to Complement GPS*, GAO-21-320SP (Washington, D.C.: May 10, 2021); and *GPS Alternatives: DOD Is Developing Navigation Systems but Is Not Measuring Overall Progress*, GAO-22-106010 (Washington, D.C.: Aug. 5, 2022).

[30]Additive manufacturing, also known as 3-D printing, is a computer-controlled process that creates physical objects by depositing materials, usually in layers. Additive manufacturing can produce complex objects that would be difficult or impossible to produce using traditional manufacturing methods.

[31]Carbon-carbon is a composite material composed of carbon fibers weaved together and infused with a carbon-based resin. The composite material is cured in a process called densification that requires high temperatures and months of time, according to DOD officials and industry representatives. The alternative manufacturing method, called rapid densification, could significantly reduce the densification time.

- There is a limited number of suppliers for critical components including solid rocket motors and thermal protection materials. In some cases, only one supplier exists for the specialized components DOD needs, which reduces opportunities for competition. Additionally, with multiple concurrent hypersonic weapon development efforts, some components come from the same limited pool of suppliers, further straining the industrial base. Some components, such as solid rocket motors and carbon-carbon materials, are also in demand for other weapon systems, further complicating these problems.
- Some critical components require long lead times for production due to the processes used to manufacture them. For example, it takes months to create the specialized carbon-carbon material used for some weapons' thermal protection systems. This is because producing these materials currently requires a significant amount of manual labor as opposed to automated machinery, according to industry representatives. Other examples include solid rocket motors, specialty aluminum airframes, positioning systems, actuators, complex electrical wiring harnesses, and warheads. These long lead times can slow production rates if not considered in a timely manner and contribute to higher costs.

DOD is addressing industrial base risks for offensive hypersonic weapons through several investments made by the Office of Manufacturing Capability Expansion and Investment Prioritization. The office reported that it awarded contracts to increase the number of suppliers in the industrial base and that base's capacity and capability for manufacturing. For example, to increase the capacity and robustness of the industrial base for solid rocket motors, the office reported awarding a $64 million contract to a second supplier of solid rocket motors for LRHW and CPS. Another investment was to reduce the manufacturing time for carbon-carbon materials by using robotic additive manufacturing techniques.

The office is monitoring its industrial base investments and has established performance measures and goals, though it is too early to track progress with those measures. Office officials said that they conduct review meetings for their investments and brief the Principal Director for Hypersonics about every 6 months. The investments have performance measures and goals for specific production rates and percent reductions in costs for producing hypersonic weapon components. However, the investments have not produced components yet, since they are currently building new facilities.

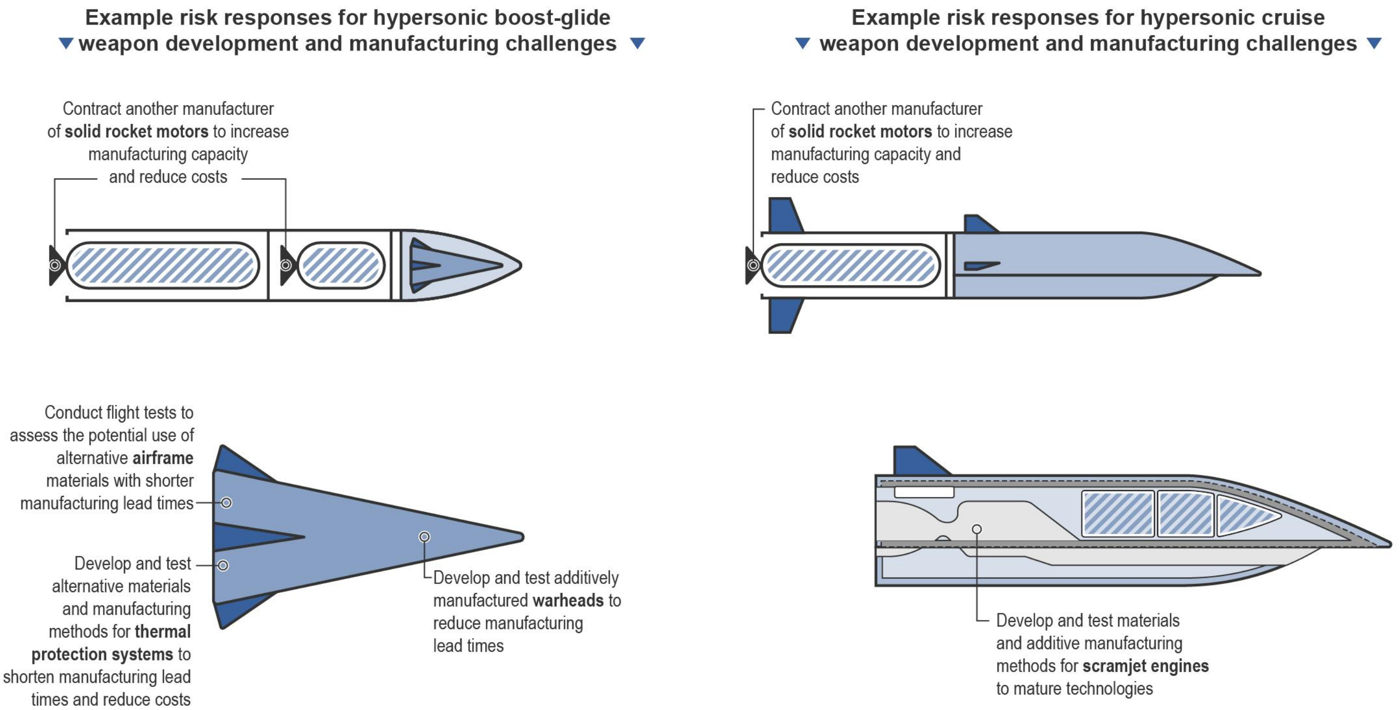
Test and evaluation. DOD has identified and assessed test and evaluation capacity and capability as major risks to the development of offensive hypersonic weapons. The risks stem, in part, from the age and insufficient sustainment and improvement of ground- and flight-test facilities due to the inconsistent focus on hypersonic systems in previous decades. In addition, test facilities and assets that support the concurrent development of multiple offensive hypersonic weapon systems also support the development of missile defense and strategic systems. As a result, the demand for ground- and flight-test facilities is much greater than what can be supported by what a DOD official said is available in federal agencies, industry, and academia. This high demand leads to schedule conflicts and could ultimately delay hypersonic weapon efforts and increase costs.

Additionally, existing test facilities and ranges, such as those to test airbreathing propulsion systems, do not reproduce all of the physical conditions associated with hypersonic flight, according to DOD officials. Without sufficient capacity to test or the capability to replicate certain physical conditions, hypersonic weapon development efforts may lack accurate information to adequately lower technical risk or validate design and performance models. Hypersonic weapon development efforts then might have to choose between adopting more conservative designs, which can limit a weapon's performance, or having lower confidence in a weapon's performance.

To address test and evaluation risks, the Test Resource Management Center is making investments to act on the highest priority needs. A center official said that the center has $1.5 billion in investments planned from fiscal years 2023 through 2028 to upgrade and expand test infrastructure. The center is making investments in ground facilities, such as building a new arc-heated facility and a new airbreathing propulsion test facility that will better replicate hypersonic flight conditions compared to existing test facilities. The center is also making several investments for flight tests, including airborne sensors and data collection platforms, more frequent and affordable flight testing, and additional test corridors. For example, the SkyRange effort converts Global Hawk and Reaper uncrewed aerial systems to collect data on test assets in flight. These aircraft can be deployed more agilely and collect certain types of data with higher quality than the crewed surface ships that traditionally support flight tests, according to DOD officials. In addition, the center is investing in the Multi-Service Advanced Capability Hypersonic Test Bed, which DOD officials expect to provide affordable and more frequent flight-test opportunities for a broad set of advanced technologies and systems across different operational hypersonic conditions. Finally, the center plans to establish long-range flight-test corridors over the Atlantic Ocean, over land in the western United States, and over the Pacific Ocean into Alaska. The U.S. is also leveraging its partnership with Australia to use its test ranges.

DOD officials said that they have established the frequency of hypersonic flight testing as a relevant performance measure to monitor test and evaluation risk and have set a goal of conducting one hypersonic flight test per week. Officials have said that the Multi-Service Advanced Capability Hypersonic Test Bed is the main method to achieving this goal. The Principal Director for Hypersonics said that he typically receives quarterly briefs from the Test Resource Management Center with less formal updates and communication occurring frequently between the more formal briefings. Center officials said that they monitor how well they address test and evaluation risks by annually reassessing shortfalls in needed capabilities and updating the hypersonic test infrastructure roadmap. Figure 8 illustrates some of DOD's risk responses for hypersonic boost-glide and cruise weapons.

Figure 8: Example Risk Responses for Hypersonic Boost-Glide and Hypersonic Cruise Weapons



Source: GAO analysis of Department of Defense and contractor information. | GAO-24-106792

Workforce. DOD has identified the potential of a limited workforce for hypersonics as a risk. The sensitive nature of hypersonic technologies and systems limits the available workforce as it requires that the workforce has the appropriate technical expertise and the ability to access classified materials. Additionally, much of the workforce with technical knowledge of hypersonics is nearing retirement. Many sectors of government and industry that need similar expertise as hypersonics, including the commercial space industry, compete with hypersonics to attract and retain the limited supply of talent, according to a DOD official. It is especially challenging to recruit talent for some high-demand occupations, such as software engineers.

To address workforce risks, the Joint Hypersonics Transition Office has taken several actions, including developing a roadmap to create a pipeline of candidates graduating from academic or technical training programs to work on hypersonics. This roadmap targets workforce gaps in and disciplines related to priority technology challenges and areas of high competition for talent. The office has also established a university consortium to give undergraduate and graduate students opportunities to conduct sensitive applied hypersonic research. Finally, it has funded internship opportunities at national laboratories, government agencies, and universities for students to gain experience in hypersonics.

The Joint Hypersonics Transition Office's workforce development team monitors and measures students' progression and its outreach with various groups. The office collects information about students working on projects it funded, including milestones such as internships, graduation, and job acquisition. The office's workforce development roadmap lists performance measures on outreach with university students, community college and technical school students, industry, mid-career professionals, educators and students, and underrepresented groups. The office briefs the Principal Director for Hypersonics on student development, training courses, and outreach activities on a quarterly basis.

DOD Is Not Comprehensively Reporting Progress on Managing Risks

DOD has not implemented the sixth, and final, essential element of an effective enterprise risk management framework: communicating and reporting on risks both internally and externally. DOD offices communicate and report on risks internally, but DOD does not do so externally in a comprehensive fashion. Sharing risk information and incorporating feedback from internal and external stakeholders can help organizations identify and better manage risks. In a federal setting, communicating risk is also important because of the additional transparency expected by Congress, taxpayers, and other relevant stakeholders. Communicating management of enterprise-level risks through a dedicated report or integrating risk information into existing enterprise-level performance management reports are useful ways of sharing progress on managing risks.

While DOD stakeholders involved in offensive hypersonic weapon efforts regularly coordinate and communicate among each other, DOD is not comprehensively communicating and reporting to Congress its progress on managing risks. Reporting comprehensive information would enable Congress to better understand and oversee DOD's progress in managing risks at the enterprise level for offensive hypersonic weapons.

DOD does provide some information to Congress on these risks. The Under Secretary of Defense for Research and Engineering must report annually on the activities and statuses of DOD's critical technology areas.[32] The Under Secretary must also report quarterly on DOD's forward-looking hypersonic science and technology development strategy as well as investments and progress toward achieving DOD's hypersonic science and technology goals.[33] Additionally, DOD has been required to report information on different test and evaluation subjects on a nonrecurring basis since at least 2019. An official from one DOD office said that the office briefs congressional staff members on investments in the industrial base through the annual budgeting process. This information, however, does not include progress on managing enterprise-level risks since the official said that the information contains limited data on individual projects.

More recently, Section 218 of the National Defense Authorization Act for Fiscal Year 2024 established new periodic reporting requirements for DOD, including an "Annual Report on Funding and Investments in Hypersonic Capabilities."[34] The statute requires DOD to include in this report information on funding and investments in "procurement, research, development, test, and evaluation, and operation and maintenance of offensive and defensive hypersonic weapons." The act, however, does not explicitly require reporting on enterprise-level risks and progress managing them.

While the reports to meet prior reporting requirements include information on DOD's activities in different areas, they do not provide comprehensive, enterprise-level information on DOD's progress across all four risk areas. DOD has not been required to report its progress on managing enterprise-level risks in this way, because existing reporting requirements have not mandated it. Without comprehensive enterprise-level reporting Congress will have an incomplete or fragmented perspective on the risks DOD has identified, the actions it is taking to address them, or the costs that these actions entail.

[32]William M. (Mac) Thornberry National Defense Authorization Act for Fiscal Year 2021, Pub. L. No. 116-283, § 217.

[33]Department of Defense Appropriations Bill, 2020, H.R. Rep. No. 116-84, at 227 (2019).

[34]National Defense Authorization Act for Fiscal Year 2024, Pub. L. No. 118-31, § 218.

Conclusions

Years of effort and billions of dollars spent on hypersonic weapon development have yielded considerable progress, but DOD has yet to field its first operational hypersonic weapon system. Yet even fielding these first prototypes will not ensure an effective or affordable capability. Direct and continuous feedback from potential users on product development efforts assists developers in prioritizing and delivering the most essential capabilities quickly and ensuring that the insertion of capabilities in the future meets the warfighters' needs. Expanded use of modern digital engineering tools will help these efforts to iterate more quickly on designs than is possible with physical prototyping alone. Given the risks identified by DOD in estimating costs for hypersonic weapons, improvements to cost estimating based on leading practices will help DOD plan better and allocate resources. Finally, by providing additional information to Congress, DOD will provide additional transparency on its progress implementing enterprise-level solutions for hypersonics and the costs associated with addressing identified risks.

Recommendations for Executive Action

We are making the following 10 recommendations to DOD:

The Secretary of the Navy should ensure the Standard Missile 6 (SM-6) Block IB effort solicits and incorporates relevant user feedback throughout development. (Recommendation 1)

The Secretary of the Air Force should ensure the Hypersonic Attack Cruise Missile effort solicits and incorporates relevant user feedback throughout development. (Recommendation 2)

The Secretary of the Navy should ensure the Hypersonic Air-Launched Offensive anti-surface warfare effort solicits and incorporates relevant user feedback throughout development. (Recommendation 3)

The Secretary of the Air Force should ensure the Air-launched Rapid Response Weapon effort, if further development and production is planned, solicits and incorporates relevant user feedback throughout development. (Recommendation 4)

The Secretary of the Army should ensure the Long-Range Hypersonic Weapon effort assesses the practicality, benefits, and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort. (Recommendation 5)

The Secretary of the Navy should ensure that the Standard Missile 6 (SM-6) Block IB effort assess the practicality, benefits, and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort. (Recommendation 6)

The Secretary of the Air Force should ensure the Air-launched Rapid Response Weapon effort, if further development and production is planned, assesses the practicality, benefits, and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort. (Recommendation 7)

The Secretary of the Air Force should ensure the Hypersonic Attack Cruise Missile effort assesses the practicality, benefits, and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort. (Recommendation 8)

The Secretary of the Navy should ensure the Conventional Prompt Strike program office improves its cost model in accordance with the “accurate” characteristic described in GAO’s *Cost Estimating and Assessment Guide*, including by estimating each element using the best methodology from the data collected and updating the estimate to reflect program changes and actual costs. (Recommendation 9)

The Secretary of Defense should ensure that the Under Secretary of Defense for Research and Engineering periodically provides information on DOD’s progress in managing enterprise-level risks to congressional decision-makers. (Recommendation 10)

Agency Comments and Our Evaluation

We provided a draft of this report to DOD for review and comment. DOD provided an official comment letter (reproduced in appendix II) which concurred with our recommendations. They also provided technical comments which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Defense, the Secretary of the Air Force, the Secretary of the Army, the Secretary of the Navy, and other interested parties. In addition, the report is available at no charge on the GAO website at https://www.gao.gov/.

If you or your staff have any questions concerning this report, please contact us at (202) 512-4841 or ludwigsonj@gao.gov and at (202) 512-6888 or bothwellb@gao.gov. Contact points for our Offices of

Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are listed in appendix III.

Jon Ludwigson, Director
Contracting and National Security Acquisitions

Brian Bothwell, Director
Science, Technology Assessment, and Analytics

List of Committees

The Honorable Jack Reed
Chairman
The Honorable Roger Wicker
Ranking Member
Committee on Armed Services
United States Senate

The Honorable Jon Tester
Chair
The Honorable Susan Collins
Ranking Member
Subcommittee on Defense
Committee on Appropriations
United States Senate

The Honorable Mike Rogers
Chairman
The Honorable Adam Smith
Ranking Member
Committee on Armed Services
House of Representatives

The Honorable Ken Calvert
Chair
The Honorable Betty McCollum
Ranking Member
Subcommittee on Defense
Committee on Appropriations
House of Representatives

Appendix I: Objectives, Scope, and Methodology

The Joint Explanatory Statement accompanying the James M. Inhofe National Defense Authorization Act for Fiscal Year 2023 included a provision that GAO conduct a review of the offensive hypersonic weapons programs of the Department of Defense. We defined hypersonic vehicles in a previous report as those that (1) travel at speeds of Mach 5 or greater, (2) spend a majority of their flight path inside the atmosphere, and (3) are capable of maneuvering in flight.[1] For this report, we added a fourth element: that the system is designed to provide an operational, offensive strike capability.

Using this definition, we identified six offensive hypersonic weapon development efforts for inclusion in this review: (1) the Army's Long-Range Hypersonic Weapon (LRHW), (2) the Navy's Conventional Prompt Strike (CPS), (3) the Air Force's Air-launched Rapid Response Weapon (ARRW), (4) the Air Force's Hypersonic Attack Cruise Missile (HACM), (5) the Navy's Hypersonic Air-Launched Offensive anti-surface warfare weapon (HALO), and (6) the Navy's Standard Missile 6 (SM-6) Block IB. To validate this selection, we consulted with DOD's Principal Director for Hypersonics, who confirmed that the six efforts met our definition and no other efforts within his portfolio met these criteria.

This report examines (1) the acquisition approaches DOD is using for offensive hypersonic weapons, (2) the extent to which DOD is employing leading practices for product development to address risks associated with the schedule and performance of these weapons, (3) the extent to which DOD has identified and analyzed cost risks for these weapons, (4) the extent to which DOD is managing enterprise-level risks for the development of hypersonic systems.

To identify the acquisition approaches used by DOD for its offensive hypersonic development efforts, we interviewed officials from each of the identified efforts about the status and history of these efforts. We reviewed key documents from these efforts, including acquisition strategies, acquisition decision memorandums, and briefings.

To determine the extent to which DOD employed leading practices for product development to address risks associated with the schedule and performance of these weapons, we reviewed documents provided by the Army, Air Force, and Navy and interviewed officials from the six efforts' offices. These documents included schedules, requirements, and other documentation. We also reviewed DOD instructions and guidance for the middle tier of acquisition and major capability acquisition pathways. We assessed the efforts by comparing this information to our leading practices for product development.[2] We focused on the principles most relevant to the six identified efforts based on their phase of product development: prioritizing schedule by off-ramping capabilities when necessary, soliciting user feedback to inform a minimum viable product, and the use of digital engineering tools such as digital twinning.

[1]GAO, *Hypersonic Weapons: DOD Should Clarify Roles and Responsibilities to Ensure Coordination across Development Efforts*, GAO-21-378 (Washington, D.C.: Mar. 22, 2021).

[2]GAO, *Leading Practices: Agency Acquisition Policies Could Better Implement Key Product Development Principles*, GAO-22-104513 (Washington, D.C.: Mar. 10, 2022); and *Leading Practices: Iterative Cycles Enable Rapid Delivery of Complex, Innovative Products*, GAO-23-106222 (Washington, D.C.: July 27, 2023)

To assess DOD's efforts to identify and analyze cost risks, we interviewed DOD officials and industry representatives regarding cost issues. We reviewed high-level cost estimates for each effort. We then performed a more detailed assessment of the CPS effort's rapid fielding cost estimate based on its adherence to our leading practices for the "accurate" characteristic. We selected the CPS cost estimate for assessment because the effort was among the most mature of the six identified and the Navy prepared the cost estimate to inform a major acquisition decision. We chose the "accurate" characteristic because, among the four characteristics, it was most relevant to the scope of this report.

To perform this assessment, we obtained and analyzed portions of the draft CPS rapid fielding cost estimate and documentation supporting the Navy's cost estimating practices. For the portions we could not access, we interviewed CPS cost estimators as they guided us through a copy of the estimate. We assessed the CPS cost estimate by comparing the estimates and supporting documentation to the leading practices discussed in our *Cost Estimating and Assessment Guide*.[3] These practices have been found to be the basis for reliable cost estimates. In making these assessments, we sorted our findings into categories of fully met, substantially met, partially met, minimally met, or not met.[4] Accurate cost estimates are developed by the following: estimating each cost element using the best methodology from the data collected; using appropriate adjustments for inflation; ensuring there are few, if any, minor mathematical mistakes; being based on a historical record of cost estimating and actual experiences from comparable programs; being updated regularly to reflect significant changes in the program; and ensuring any variances between estimated and actual costs are documented, explained, and reviewed.

To determine the extent to which DOD is identifying and managing enterprise-level risks related to hypersonic systems, we interviewed DOD officials at both the enterprise level and within offices responsible for executing risk responses. We reviewed documentation from the Offices of the Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment on identifying and responding to risks. These documents included technology development roadmaps, enterprise strategies, risk analyses, and other reports describing accomplishments, setbacks, and risks. In addition, we conducted a site visit to Dynetics' Common Hypersonic Glide Body manufacturing facility, the Lockheed Martin CPS/LRHW missile assembly facility, and the LRHW Systems Integration Lab. We then assessed this information against the six elements listed in our Enterprise Risk Management framework: (1) align process to goals and objectives, (2) identify risks, (3) assess risks, (4) select risk response, (5) monitor risks, and (6) communicate and report on risks.[5]

We conducted this performance audit from April 2023 to July 2024 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain

[3] GAO, *Cost Estimating and Assessment Guide: Best Practices for Developing and Managing Program Costs,* GAO-20-195G (Washington, D.C.: Mar. 12, 2020). The *Cost Estimating and Assessment Guide* also articulates three other characteristics of a reliable cost estimate: comprehensive (meaning it reflects the current schedule and technical baselines), well-documented (meaning all parts can easily be repeated or updated and can be traced to original sources), and credible (meaning it discusses and documents any limitations, including the possibility of uncertainty or bias).

[4] "Fully met" means the Navy provided complete evidence that satisfied the entire criterion. "Substantially met" means the Navy provided evidence that satisfied a large portion of the criterion. "Partially met" means the Navy provided evidence that satisfied about half of the criterion. "Minimally met" means the Navy provided evidence that satisfied a small portion of the criterion. "Not met" means the Navy provided no evidence that satisfies any of the criterion.

[5] GAO, *Enterprise Risk Management: Selected Agencies' Experiences Illustrate Good Practices in Managing Risk*, GAO-17-63 (Washington, D.C., Dec. 1, 2016).

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

Appendix II: Comments from the Department of Defense

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

ACQUISITION

JUN 2 7 2024

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

Dear Mr. Ludwigson:

The Department has completed a security and accuracy review of Government Accountability Office (GAO) Draft Hypersonic Weapons Report 24-106792, 'DOD Could Reduce Cost and Schedule Risks by Following Leading Practices.'

The Department finds that the draft report is UNCLASSIFIED and cleared for public release, pending the GAO addressing the security and sensitivity concerns provided. Enclosed is a copy of the Department's official security review. Additionally, comments and recommended changes to the content of the draft report are enclosed.

Department concurs with all ten of the GAO recommendations provided in the draft report.

My point of contact is Mr. Brandon Sweat who can be reached at brandon.e.sweat.civ@mail.mil and phone 703-697-8183.

Sincerely,

Gary A. Ashworth
Performing the Duties of the Assistant Secretary
of Defense for Acquisition

Enclosures:
As stated

GAO DRAFT REPORT DATED APRIL 29, 2024
GAO-24-106792 (GAO CODE 106792)

"HYPERSONIC WEAPONS: DOD COULD REDUCE COST AND SCHEDULE RISKS BY FOLLOWING LEADING PRACTICES"

DEPARTMENT OF DEFENSE COMMENTS TO THE GAO RECOMMENDATION

RECOMMENDATION 1: The Secretary of the Navy should ensure the Standard Missile 6 (SM-6) Block IB efforts solicits and incorporates relevant user feedback throughout development.

DoD RESPONSE: Concur: The DON recognizes the value of user feedback across all acquisition programs, particularly MTA efforts; this feedback can help enable these programs to move at speed while also providing optimal capability to users. The Joint Urgent Operational Needs statement and Nimble Fire war games were instances of user feedback which informed early conceptual design and systems trades that in turn facilitated the inception of SM-6 Block IB. The DON has instituted a framework in which the program office collaborates with the Naval Surface and Mine Warfighting Development Command, leveraging feedback from the Navy's Weapons Tactics Instructors, and is engaged with the Naval Capabilities Improvement Program (NCIP), where capability gaps and desires are discussed with the technical community, fleet representatives, and resource sponsors.

RECOMMENDATION 2: The Secretary of the Air Force should ensure the Hypersonic Attack Cruise Missile (HACM) effort solicits and incorporates relevant user feedback throughout development.

DoD RESPONSE: Concur, the HACM Program has and will continue to solicit inputs from all stakeholders throughout development. Stakeholder inputs are assessed for impact to cost, schedule, and performance prior to deciding to incorporate into the program.

RECOMMENDATION 3: The Secretary of the Navy should ensure the Hypersonic Air-Launched Offensive anti-surface warfare (HALO) effort solicits and incorporates relevant user feedback throughout development.

DoD RESPONSE: Concur. The DON recognizes the value of user feedback across all acquisition programs, particularly MTA efforts; this feedback can help enable these programs to move at speed while also providing optimal capability to users. The HALO program will solicit inputs from a diverse set of users, including immediate operators, mission planners and operational commands, maintainers, pilots, and other actors. This will be done throughout development, with a time-phased plan to incorporate feedback from each user type at the optimal time.

RECOMMENDATION 4: The Secretary of the Air Force should ensure the Air-launched Rapid Response Weapon (ARRW) effort, if further development and production is planned, solicits, and incorporates relevant user feedback throughout development.

DoD RESPONSE: Concur, if further development and production of the ARRW Program occurs, the program will solicit inputs from relevant users and will assess their impact to cost, schedule and performance prior to deciding to incorporate into the program.

RECOMMENDATION 5: The Secretary of the Army should ensure that the Long-Range Hypersonic Weapon (LRHW) effort asses the practicality, benefits, and affordability of implementing digital engineering, including digital twinning and whether to incorporate these tools into the effort.

DoD RESPONSE: Concur without specific comment.

RECOMMENDATION 6: The Secretary of the Navy should ensure that the Standard Missile 6 (SM-6) Block IB effort assess the practicality, benefits, and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort.

DoD RESPONSE: Concur. The program will continue to seek opportunities to inject digital engineering processes into SM-6 Block IB development. The program incorporated digital engineering requirements into its most recent solid rocket motor efforts, and the prime contractor employes Model Based Systems Engineering with many of their current tasks. The program also leverages both Inert Operational Missiles and Missile Simulation Units in order to increase the pace of integration and reduce costs where possible.

RECOMMENDATION 7: The Secretary of the Air Force should ensure the Air-launched Rapid Response Weapon effort, if further development and production is planned, assess the practicality benefits, and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort.

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DoD RESPONSE: Concur, the HACM Program will assess expanding its implementation of digital engineering activities to include digital twinning, as part of its transition to a major capability acquisition.

RECOMMENDATION 9: The Secretary of the Navy should ensure the Conventional Prompt Strike program office improves its cost model in accordance with the “accurate” characteristic described in GAO’s Cost Estimating and Assessment Guide, including by estimating each element using the best methodology from the data collected and updating the estimate to reflect program changes and actual costs.

DoD RESPONSE: Concur. The Conventional Prompt Strike program continuously updates its cost model in alignment with the "accurate" characteristic described in GAO's Cost Estimating and Assessment Guide. This includes updates to reflect program changes and actual costs, and incorporates the best methodology possible based on improved data availability.

RECOMMENDATION 10: The Secretary of Defense should ensure that Under Secretary of Defense for Research and Engineering periodically provides information on DoD’s progress in managing enterprise-level risks to Congressional decisionmakers.

DoD RESPONSE: Concur, agree to periodically providing information on DoD’s Hypersonic progress in managing enterprise-level risks to Congressional decisionmakers.

Accessible Text for Appendix II: Comments from the Department of Defense

JUN 27 2024

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

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RECOMMENDATION 7: The Secretary of the Air Force should ensure the Air-launched Rapid Response Weapon effort, if further development and production is planned, assess the practicality benefits, and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort.

DoD RESPONSE: Concur, if further development and production of the ARRW Program occurs, the program will, as part of acquisition decision, assess the practicality and affordability of implementing digital engineering, including digital twinning, and whether to incorporate these tools into the effort.

RECOMMENDATION 8: The Secretary of the Air Force should ensure the Hypersonic Attack Cruise Missile effort asses the practicality, benefits, and affordability of implementing digital engineering, digital twinning, and whether to incorporate these tools into the effort.

DoD RESPONSE: Concur, the HACM Program will assess expanding its implementation of digital engineering activities to include digital twinning, as part of its transition to a major capability acquisition.

RECOMMENDATION 9: The Secretary of the Navy should ensure the Conventional Prompt Strike program office improves its cost model in accordance with the “accurate” characteristic described in GAO’s Cost Estimating and Assessment Guide, including by estimating each element using the best methodology from the data collected and updating the estimate to reflect program changes and actual costs.

DoD RESPONSE: Concur. The Conventional Prompt Strike program continuously updates its cost model in alignment with the "accurate" characteristic described in GAO's Cost Estimating and Assessment Guide. This includes updates to reflect program changes and actual costs, and incorporates the best methodology possible based on improved data availability.

RECOMMENDATION 10: The Secretary of Defense should ensure that Under Secretary of Defense for Research and Engineering periodically provides information on DoD’s progress in managing enterprise-level risks to Congressional decisionmakers.

DoD RESPONSE: Concur, agree to periodically providing information on DoD’s Hypersonic progress in managing enterprise-level risks to Congressional decisionmakers.

Appendix III: GAO Contact and Staff Acknowledgments

GAO Contacts

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