Report No. DODIG-2020-003

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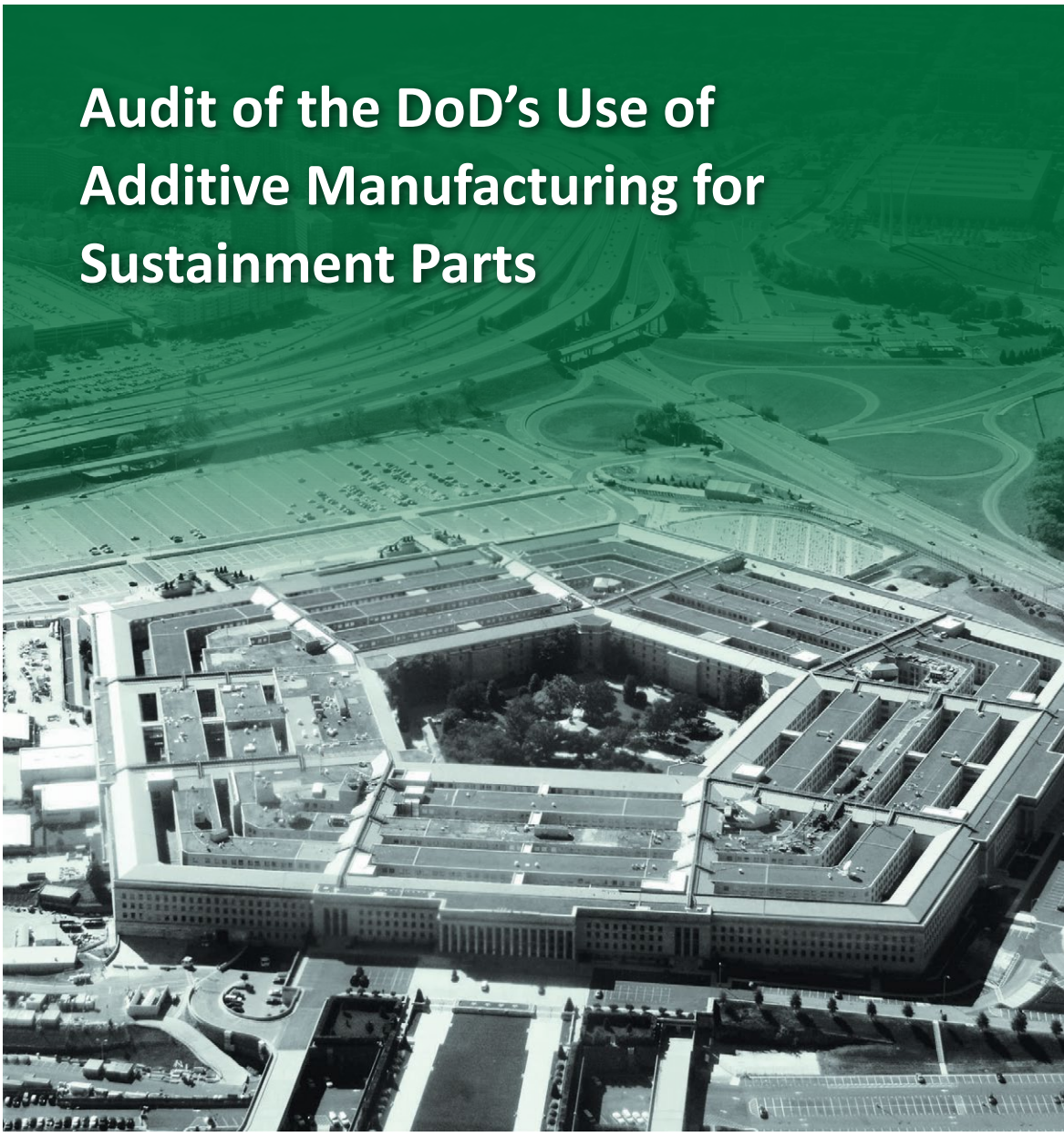
INSPECTOR GENERAL

U.S. Department of Defense

OCTOBER 17, 2019

Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts



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Results in Brief

Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts

October 17, 2019

Objective

The objective of this audit was to determine the extent to which the DoD used additive manufacturing (AM) when obtaining sustainment parts. Specifically, we evaluated the DoD's actions to implement AM for the sustainment of equipment and weapon systems, including the coordination of AM efforts across the DoD. In this report, "sustainment parts" refers to parts being replaced on existing weapon systems. Our review also included the tools and molds produced through AM that were used to sustain weapon systems.

Background

AM creates an object by adding layers of material from three-dimensional data, unlike traditional, or subtractive, manufacturing processes where the product is created by cutting away material from a larger piece. This process also includes 3-D printing. Examples of AM materials include plastics, metals, and ceramics.

The National Defense Authorization Act for FY 2017 Senate Report "strongly encouraged" the DoD to more aggressively pursue AM capabilities to improve readiness and enable the Military Services to be more self-sustainable.

The Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy is the DoD AM lead that oversees the implementation of AM and reports to the Under Secretary of Defense for Research and Engineering.

Finding

The Office of the Secretary of Defense implemented policy and established multiple working groups to coordinate efforts between the Military Services and the Defense Logistics

Finding (cont'd)

Agency (DLA). In addition, at least 81 Military Service depots, maintenance facilities, and field locations have used AM to produce thousands of AM parts and tools, such as cooling ducts, clips, and wrenches, to decrease maintenance time, reduce the impact of obsolete parts that are no longer available through traditional manufacturing sources, and improve existing parts.

However, the DoD could expand the use of AM to obtain sustainment parts by:

- standardizing the data elements captured for AM parts produced to ensure consistency in production, standardizing reporting requirements for AM equipment and funds spent to understand where the DoD is investing its resources, and standardizing the cataloging of AM parts to ensure the AM data are consistent and complete;
- implementing a method for sharing AM parts data within the Military Services and across the DoD to eliminate duplicative efforts when designing and producing AM parts;
- increasing awareness of AM among officials in acquisition, contracting, logistics, and senior DoD management to identify additional AM candidate parts; and
- identifying the staffing and funding necessary to accomplish AM initiatives.

~~(FOUO)~~ These actions could increase the use of AM and improve warfighter readiness by decreasing the lead and repair times from years to days for some hard-to-procure parts that can be produced through AM. For example, the Navy used AM to produce an MH-60R sonar system cover. This AM part reduced the time it took to receive the part from 2 years to 1 week and decreased cost from $[redacted] to $[redacted] per cover.

In addition, the DoD could save funds by eliminating duplicative AM efforts, using AM for low-quantity and high-cost parts that are hard to obtain, and using AM to replace a single part rather than an entire component if the parts are found to be appropriate for AM. For example, an F-35 landing gear door bump stop has to be purchased as part of the traditionally produced landing gear assembly for $70,000; however, the Navy used AM to produce the bump stop for only $0.75. The AM-produced part made it unnecessary for the Navy to purchase the entire assembly.

Results in Brief

Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts

Recommendations

We recommend that the Under Secretary of Defense for Research and Engineering standardize the data to be reported by the Military Services and the DLA for AM parts produced, AM equipment available, and amount spent on AM.

We recommend that the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment:

- develop policy that standardizes the cataloging of AM parts;
- develop and require the Military Services and the DLA to implement a single method to share data on AM parts; and
- provide awareness of AM and its capabilities to the Military Services and the DLA program officers, logisticians, contracting officers, and senior DoD management and require the Military Services and the DLA to update its AM guidance.

We recommend that the Military Service Secretaries and the Marine Corps Commandant require the AM leads to implement a process that compiles a complete list of all AM parts produced and parts waiting for approval to share within each Military Service, and update the list as needed.

We recommend that the Under Secretary of Defense for Research and Engineering, Under Secretary of Defense for Acquisition and Sustainment, the Military Service Secretaries, and the Marine Corps Commandant conduct a review to identify the appropriate funding and number of personnel to pursue benefits of AM throughout the DoD.

Management Comments and Our Response

The Navy, Air Force, and Marine Corps agreed to implement a process to compile a complete list of AM parts and are working to make these parts accessible to the Military Services. Management comments addressed the specifics of the recommendation; therefore, the recommendation is resolved but will remain open. We will close the recommendation once the Navy, Air Force, and Marine Corps provide documentation verifying they have compiled complete and accessible lists of the parts produced and parts awaiting approval.

The Navy, Air Force, and Marine Corps also agreed to identify the appropriate funding and number of personnel to pursue the benefits of AM. Management comments addressed the specifics of the recommendation; therefore, the recommendation is resolved but will remain open. We will close the recommendation once the Navy, Air Force, and Marine Corps provide documentation verifying they have developed an estimate of the appropriate funding and staffing levels for the specific tasks.

The Under Secretary of Defense for Research and Engineering, Under Secretary of Defense for Acquisition and Sustainment, and Secretary of the Army did not respond to the recommendations in the report. Therefore, the recommendations to these individuals are unresolved. We request that the Under Secretaries and the Secretary of the Army provide comments on the final report. Please see the Recommendations Table on the next page for the status of recommendations.

Recommendations Table

Management	Recommendations Unresolved	Recommendations Resolved	Recommendations Closed
Under Secretary of Defense for Research and Engineering	1.a, 1.b, 2.a, 2.c, 2.d, 4	None	None
Under Secretary of Defense for Acquisition and Sustainment	2.a, 2.b, 2.c, 2.d, 4	None	None
Secretary of the Navy	None	3, 4	None
Secretary of the Army	3, 4	None	None
Secretary of the Air Force	None	3, 4	None
Commandant of the Marine Corps	None	3, 4	None

Please provide Management Comments by November 18, 2019.

Note: The following categories are used to describe agency management's comments to individual recommendations.

- **Unresolved** – Management has not agreed to implement the recommendation or has not proposed actions that will address the recommendation.
- **Resolved** – Management agreed to implement the recommendation or has proposed actions that will address the underlying finding that generated the recommendation.
- **Closed** – OIG verified that the agreed upon corrective actions were implemented.


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October 17, 2019

MEMORANDUM FOR UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING
UNDER SECRETARY OF DEFENSE FOR ACQUISITON AND SUSTAINMENT
DIRECTOR, DEFENSE LOGISTICS AGENCY
AUDITOR GENERAL, DEPARTMENT OF THE NAVY
AUDITOR GENERAL, DEPARTMENT OF THE ARMY
AUDITOR GENERAL, DEPARTMENT OF THE AIR FORCE

SUBJECT: Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts (Report No. DODIG-2020-003)

This final report provides the results of the DoD Office of Inspector General's audit. We previously provided copies of the draft report and requested written comments on the recommendations. We considered management's comments on the draft report when preparing the final report. Comments from the Navy, Air Force, and Marine Corps are included in the report and conformed to the requirements of DoD Instruction 7650.03. Therefore, we do not require additional comments from these offices.

This report contains recommendations that are considered unresolved because the Under Secretary of Defense for Research and Engineering, Under Secretary of Defense for Acquisition and Sustainment, and Secretary of the Army did not provide a response to the report. Therefore, as discussed in the Recommendations, Management Comments, and Our Response section of this report, the recommendations remain open. We will track these recommendations until an agreement is reached on the actions to be taken to address the recommendations, and adequate documentation has been submitted showing that the agreed-upon action has been completed.

DoD Instruction 7650.03 requires that recommendations be resolved promptly. Therefore, please send a PDF file containing your comments on the recommendations within 30 days to audclev@dodig.mil. If you arrange to send classified comments electronically, you must send them over the SECRET Internet Protocol Router Network (SIPRNET). Copies of your comments must have the actual signature of the authorizing official for your organization.

We appreciate the cooperation and assistance received during the audit. Please direct questions to [redacted] at [redacted].

Theresa S. Hull
Assistant Inspector General for Audit
Acquisition, Contracting, and Sustainment

Contents

Introduction

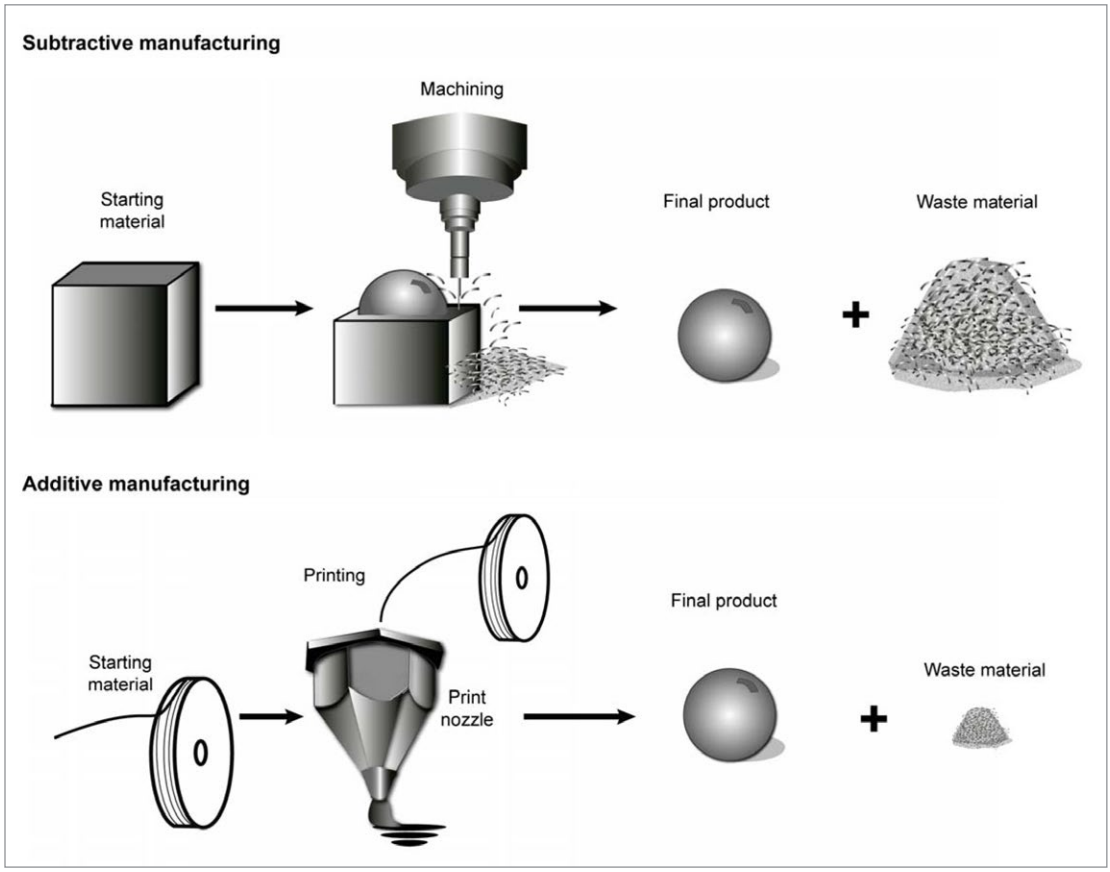
Objective

The objective of this audit was to determine the extent the DoD used additive manufacturing (AM) when obtaining sustainment parts. Specifically, we evaluated the DoD's actions to implement AM for the sustainment of equipment and weapon systems, including the coordination of AM efforts across the DoD. In this report, "sustainment parts" refers to parts being replaced on existing weapon systems. Our review also included the tools and molds produced through AM that were used to sustain weapon systems. See Appendix A for a discussion of the scope and methodology and prior audit coverage related to the objective.

Background

AM creates an object by adding layers of material from three-dimensional data, unlike traditional, or subtractive, manufacturing processes where the product is created by cutting away material from a larger piece. This process also includes 3-D printing, and examples of AM materials include plastics, metals, and ceramics. Figure 1 shows the subtractive and AM manufacturing processes.

Figure 1. Subtractive and AM Processes



Source: Government Accountability Office Report GAO-16-56.

Establishing DoD Additive Manufacturing

Multiple DoD Components conduct research and development, maintenance, and production activities for parts produced by AM (AM parts). Although AM has been widely used in the DoD's maintenance and sustainment enterprise for more than 15 years, the DoD began collaborating in 2012 with America Makes to advance AM efforts between Federal Government agencies, private industry, and universities. Leaders from the Office of the Secretary of Defense (OSD) participated in a Government Accountability Office (GAO) forum in October 2014 on using AM to produce parts. The forum topics included opportunities, challenges, and policy considerations that could affect the future use of AM. In October 2015, the GAO found that the DoD took steps to implement AM, but did not systematically track DoD Components' efforts DoD-wide.[1] By spring 2016, the Army, Navy, Air Force, and Defense Logistics Agency (DLA) had each created technology roadmaps for AM. These roadmaps included each group's vision and the common technology gaps between the current state and the future vision. Subsequently, the DoD created a joint DoD roadmap that identifies commonality between the Military Service and DLA roadmaps. The DoD roadmap included commonalities such as reducing logistics lead time, accelerating AM adoption, and developing the digital infrastructure.

The National Defense Authorization Act (NDAA) for FY 2017 Senate Report "strongly encouraged" the DoD to more aggressively pursue AM capabilities to improve readiness and enable the Military Services to be more self-sustainable.[2] According to an official with the Assistant Secretary of the Navy for Research, Development, Test, and Evaluation, the NDAA for FY 2017 Senate Report led the DoD to shift its AM focus from research and development to sustainment. In July 2017, the DoD identified the Office of the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy as the DoD AM lead. After the 2018 reorganization of the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics, the office was split into the Under Secretary of Defense (USD) for Research and Engineering (R&E) and the USD for Acquisition and Sustainment (A&S). Because the USD(R&E) and the USD(A&S) both fall under the OSD, in this report we refer to both organizations together as "the OSD." The Manufacturing and Industrial Base Policy office responsible for AM now reports to the USD(R&E).

[1] GAO-16-56, "DoD Needs to Systematically Track Department-Wide 3D Printing Efforts," October 2015.

[2] National Defense Authorization Act for FY 2017, Senate Report 114-255, May 18, 2016.

DoD Offices Leading Additive Manufacturing Efforts

Office of the Secretary of Defense

The USD(R&E), in coordination with the USD(A&S), oversees the DoD's implementation of AM. The USD(R&E) aligns AM investments with the DoD's priorities and leads the Joint AM Steering Group (JAMSG) and the Joint AM Working Group, which disseminate information on the DoD's AM efforts throughout the DoD Components and provide recommendations for the joint AM investment strategy.[3]

The USD(A&S) reviews and develops AM policy pertaining to acquisition. In addition, the USD(A&S) tasked the Assistant Secretary of Defense for Sustainment to monitor and review the implementation of AM sustainment policy and to lead the DoD AM for Maintenance Operations Working Group.[4] The DoD AM for Maintenance Operations Working Group is working to develop an integrated strategic vision and implement AM in support of weapon system maintenance.

United States Army

The Deputy Chief of Staff for Logistics of Headquarters, Department of the Army, oversees logistics policies and procedures for maintenance and equipment readiness. This logistics office is developing an Army interim AM policy. The Army Materiel Command is the Army's lead for AM implementation. In addition, the Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology and the Army Materiel Command prepared a campaign plan in November 2018 that developed a strategy and framework to help realize the full potential of AM. Finally, the U.S. Army Training and Doctrine Command and the Combined Arms Support Command are responsible for developing an AM training strategy for the sustainment community.

United States Navy

The Deputy Chief of Naval Operations for Fleet Readiness and Logistics is the Navy lead for AM implementation. The Office of the Assistant Secretary of the Navy Research, Development, Test, and Evaluation; the Office of the Chief of Naval Operations for Fleet Readiness and Logistics; and Headquarters Marine Corps Installations and Logistics updated the original January 2016 AM implementation

[3] The JAMSG and the Joint AM Working Group consist of the OSD, the Military Services, DoD Components, and Joint Staff. The JAMSG members are senior officials and the JAMSG appoints the working group members.

[4] The DoD AM for Maintenance Operations Working Group consists of the OSD, the Military Services, the DLA, other Government agencies, and private industry.

plan in 2017 to identify increased readiness and enhanced warfighter capabilities as its AM goals. In addition, Naval Air Systems Command (NAVAIR) and Naval Sea Systems Command (NAVSEA) developed guidance on the use of AM and Naval Supply Systems Command is developing contracting and acquisition guidance.[5]

United States Air Force

The Air Force Life Cycle Management Center, Product Support Engineering Division, is the Air Force lead for AM implementation. This division developed a strategic plan in October 2016 to implement AM by using standard processes and AM printers. The Air Force's vision for the future is the ability to produce a part on demand, anytime, anywhere, and on any machine.

United States Marine Corps

Headquarters, Marine Corps Installations and Logistics is the Marine Corps lead for AM-related collaboration with the Navy and other DoD stakeholders. This office published guidance and policy on implementing AM and, in January 2018, developed the AM Concept of Employment to integrate AM across the Marine Corps.[6] The Marine Corps Systems Command provides guidance on the tracking and reporting of AM equipment and items produced using AM, and manages the digital repository, which allows Marines to share information on the AM items that they have produced.

Defense Logistics Agency

The DLA plans to use AM to solve procurement problems related to sustaining legacy repair parts and is working to store AM data and share the data between the Military Services. DLA Logistics Operations develops the policies and procedures that define operations of the supply chain and describe the items the DLA procures for the Military Services. The DLA is also responsible for establishing processes and procedures for integrating AM into the supply chain and for providing a capability to enable DoD Components to procure, securely access, and share AM technical data.

[5] NAVSEA Message, "Issuing of Guidance on the Use of AM," September 11, 2018; NAVSEA, "Policy on the Use of AM," January 12, 2015; NAVSEA Letter 4870, "Guidance on the Use of AM," August 17, 2018; and NAVAIR Message, "Interim Guidance to Request and Employ AM Technologies Components on Naval Aircraft and Associated Equipment," March 14, 2018.

[6] Marine Administration Message Number 489/16, "Interim Policy on the Use of AM (3D Printing) in the Marine Corps," September 16, 2016; Marine Administration Message Number 594/17, "Headquarters Marine Corps Procedural Guidance Update on the Management and Employment of AM," October 25, 2017; and Marine Administration Message Number 055/19, "Headquarters Marine Corps Procedural Guidance Update Number Two on the Management and Employment of AM," January 30, 2019.

Review of Internal Controls

DoD Instruction 5010.40 requires DoD organizations to implement a comprehensive system of internal controls that provides reasonable assurance that programs are operating as intended and to evaluate the effectiveness of the controls. We identified internal control weaknesses related to the use of AM to obtain sustainment parts. Specifically, the OSD, the Military Services, and the DLA should standardize data and reporting requirements and the cataloging of AM parts; share data on AM parts; increase workforce awareness of AM; and identify the staffing and funding necessary to accomplish AM initiatives. We will provide a copy of the report to the senior official responsible for internal controls in the OSD and Military Departments.

Finding

The DoD Could Increase the Use of Additive Manufacturing

The OSD implemented policy and established multiple working groups to coordinate efforts between the Military Services and the DLA. In addition, at least 81 Military Service depots, maintenance facilities, and field locations have used AM to produce thousands of AM parts and tools to decrease maintenance time, reduce the impact of obsolete parts that are no longer available through traditional manufacturing sources, and improve existing parts. However, the DoD could expand the use of AM to obtain sustainment parts by:

- standardizing the data elements captured for AM parts to ensure consistency in production, standardizing reporting requirements for AM equipment and funds spent to understand where the DoD is investing its resources, and standardizing the cataloging of AM parts to ensure the AM data are consistent and complete;
- implementing a method for sharing AM parts data within the Military Services and across the DoD to eliminate duplicative efforts when designing and producing AM parts;
- increasing awareness of AM among officials in acquisition, contracting, logistics, and senior DoD management to identify additional AM candidate parts; and
- identifying the staffing and funding necessary to accomplish AM initiatives.

These actions could increase the use of AM and improve warfighter readiness by decreasing the lead and repair times from years to days for some hard-to-procure parts that can be produced through AM. In addition, the DoD could save funds by sharing information and progress on AM-produced parts, using AM for low-quantity and high-cost parts that are hard to obtain, and replacing a single part rather than an entire component if the part is found to be appropriate for AM.

DoD Implementation of Additive Manufacturing

The DoD is progressing with the implementation and use of AM to obtain sustainment parts since the issuance of the NDAA for FY 2017 Senate Report. Specifically, the OSD has implemented policy and created working groups, which disseminate information on the DoD's AM efforts throughout the DoD Components and provide recommendations for the joint AM investment strategy. In addition,

at least 81 Military Service depots, maintenance facilities, and field locations have used AM to produce thousands of AM parts and tools, such cooling ducts, clips, and wrenches, for the sustainment of weapon systems. The benefits of AM include improving readiness by reducing the time needed to return equipment back to a usable condition, reducing the impact of obsolete parts that are no longer available through traditional manufacturing sources, and improving existing parts by using a new design.

The benefits of AM include improving readiness by reducing the time needed to return equipment back to a usable condition.

Office of the Secretary of Defense Progress in Additive Manufacturing

The OSD coordinated efforts between the Military Services and the DLA and implemented policy to use AM to transform maintenance operations and supply chains, improve self-sustainment, and increase force readiness. Since 2017, the OSD has increased communications on the value and use of AM by leading multiple working groups with the Military Services and the DLA. For example, the Joint AM Working Group identified eight priorities for FYs 2019 and 2020, including sharing data and best practices, addressing cybersecurity concerns, and qualifying and certifying AM parts and processes. In March 2019, the USD(A&S) issued interim guidance that delegated responsibility to the OSD, the Military Services, and the DLA regarding the DoD's use of AM for sustainment parts.[7] In addition, the USD(R&E) is funding AM projects through the partnership with America Makes. One of the AM projects being funded through America Makes is a joint data exchange, called the Joint AM Model Exchange (JAMMEX), to share AM data across the Military Services and the DLA. The initial version of JAMMEX was expected to be released in August 2019.

Army Progress in Using Additive Manufacturing

As of February 2019, at least 19 Army locations were using AM to supplement the current supply chain and increase soldier readiness. These locations included maintenance depots, engineering commands, and deployed units. For example, the Army developed a transportable system called the Rapid Fabrication via AM on the Battlefield (R-FAB) that contains industrial-grade AM equipment. The R-FAB has allowed the Army to improve soldier readiness and return combat-damaged equipment back to service by expanding the use of AM at field units around the world. The Army has deployed the R-FAB to Germany, Thailand, Japan, and South Korea to identify uses and advantages of AM. Figure 2 shows an R-FAB expandable

[7] USD(A&S), Directive-Type Memorandum-19-006, "Interim Policy and Guidance for the Use of AM in Support of Materiel Sustainment," March 21, 2019.

shelter. Army policy allows an Army commander to use a risk-based approach to determine which part to produce using AM.[8] Under the current policy, the Army uses the AM part as a temporary replacement until the traditionally manufactured part arrives. The AM part must still meet the performance requirements of its intended use and are analyzed after being used.

Figure 2. R-FAB Expandable Shelter
Source: The Army.

Deployed Army units track AM parts and tools produced using the Army Materiel Command's online repository called the Repository of Additive Parts for Tactical and Operational Readiness. This repository allows Army users to view and download approved tools and weapon system parts that were designed by other units. In addition, the repository allows users to request engineering support and obtain information on part specifications for difficult designs.

The Army has successfully used AM for parts and tools to decrease maintenance time and cost. For example, the R-FAB used AM to design and produce the AH-64D Apache Helicopter (AH-64D) strap pack support, a tool used by helicopter maintenance personnel to help uninstall and reinstall the rotor blades. When maintenance personnel performed this work prior to the production of the AH-64D strap pack support, they were damaging other parts. The creation and use of the support saved 12.4 maintenance hours and $20,000 to replace the parts that may have been damaged without the AH-64D strap pack support. The strap pack support took only 9 hours to produce at a cost of $3.21. Figure 3 shows an AM-produced AH-64D strap pack support.

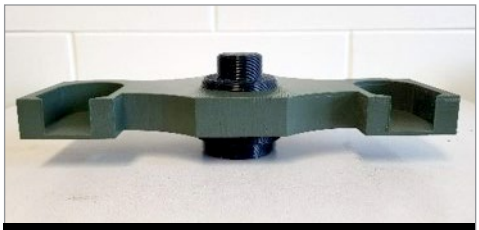


Figure 3. AM-Produced AH-64D Strap Pack Support
Source: The Army.

Navy Progress in Using Additive Manufacturing

As of January 2019, 23 Navy locations were using AM to increase readiness and sustainment and enhance warfighter capabilities. These locations included maintenance depots and warfare centers. In addition, the Navy is using AM

[8] Army Execution Order 050-18, "Guidance for the Use of Additive Manufacturing Equipment and Software," December 2017

aboard ships. For example, Fleet Readiness Center Southwest engineering staff and logisticians are using AM to address challenges, such as parts that are expensive to replace or that routinely break. The Navy uses AM printers for conducting research and development and making tools and hard-to-source and obsolete parts. NAVAIR determines which aircraft parts to produce using AM and NAVSEA determines which parts to produce for ships and submarines. According to a Chief of Naval Operations official, producing AM tools does not require prior approval. However, a NAVSEA official stated that approval is required for AM tools, molds, or fixtures to be used on a ship and nuclear equipment.

The Navy uses the Joint Technical Data Integration (JTDI), Excel spreadsheets, and an Access database to track AM parts. The JTDI allows users to search and upload approved part designs to share within the Navy AM community. The JTDI includes NAVAIR and NAVSEA AM parts under consideration and approved for production.

~~(FOUO)~~ The Navy has successfully used AM parts and tools to reduce cost and improve readiness and part performance. For example, the Navy used AM to produce an MH-60R Sea Hawk Helicopter (MH-60R) sonar system cover, which was not always available in the supply system. The AM-produced sonar system cover eliminated corrosion of the traditionally manufactured cover, reduced the lead time from 2 years to 1 week, and decreased cost from $[redacted] to $[redacted] per cover. Figure 4 shows a traditionally manufactured and an AM-produced MH-60R sonar cover.

Figure 4. Traditionally Manufactured and AM-Produced MH-60R Airborne Low Frequency Sonar Covers
Source: The Navy.

Air Force Progress in Using Additive Manufacturing

As of February 2019, at least 35 Air Force locations were using AM to reduce costs and to produce obsolete parts that are no longer available through traditional manufacturing sources. These 35 locations included maintenance depots, engineering commands, and research facilities. The Air Force is focusing on low-risk items, such as support equipment, tools, and noncritical weapon system components to establish a foundation that will allow it to expand to items that are more critical. The Air Force Life Cycle Management Center, Product Support Engineering Division, and the Air Force Research Laboratory are conducting research to develop AM capabilities. In addition, the Air Force Reverse Engineering and Critical Tooling (REACT) laboratory is reverse-engineering parts and producing parts and tools with AM. The Air Force tracks the produced parts, as well as parts waiting for approval, with an Access database and Excel spreadsheets. Engineers and other subject-matter experts review and approve AM-produced parts prior to their use.

The Air Force has achieved cost savings on parts produced using AM. For example, a software maintenance group official at Tinker Air Force Base projected a $378,000 cost savings by producing AM parts to assist with testing during FY 2019.[9] In addition, the Air Force used AM to produce three C-17 Globemaster III aircraft (C-17) cooling ducts. According to the Air Force, these AM-produced cooling ducts reduced the lead time by 9 months and could potentially save $12 million over a 20-year life cycle. Figure 5 shows an AM-produced C-17 cooling duct.

Figure 5. AM-Produced C-17 Cooling Duct
Source: The Air Force.

Marine Corps Progress in Using Additive Manufacturing

The Marine Corps is using AM at maintenance depots and expeditionary units to reduce the lead time for sustainment parts and to resolve battlefield challenges. The use of AM by the three Marine Expeditionary Forces allows the warfighter to manufacture on demand. According to the Marine Corps Systems Command, the Marine Expeditionary Forces will deploy with a transportable Expeditionary

[9] The AM parts produced are used on the Interface Test Adapter.

Fabrication Facility that contains three AM printers. As of February 2019, the Marine Corps planned to deploy the Expeditionary Fabrication Facility to 21 units by FY 2024 to supplement the supply chain and return combat-damaged equipment back to service. Figure 6 shows an Expeditionary Fabrication Facility.

Figure 6. Expeditionary Fabrication Facility
Source: The Marine Corps.

The Marine Corps is also using AM printers to develop replacement parts at the Marine Air Ground Task Force Training Command in Twentynine Palms, California. The maintenance depots and expeditionary units are using JTDI and the Marine Maker website to track parts produced using AM or parts waiting for approval for AM. The Marine Corps uses JTDI to store AM parts data and designs for aviation parts, while the Marine Maker website stores the technical data for parts and tooling for ground units.

The Marine Corps has successfully used AM to improve readiness and reduce cost in the field. For example, the Marine Corps used AM to produce an H-1 helicopter (H-1) helmet visor clip, reducing the production time from 270 days to 10 days at a cost of $0.75 to produce each clip instead of $300. Figure 7 shows an AM-produced H-1 helmet visor clip.

Figure 7. AM-Produced H-1 Helmet Visor Clip
Source: The Marine Corps.

Defense Logistics Agency Progress in Using Additive Manufacturing

The DLA is supporting the use of AM across the Military Services by designing software to identify potential AM candidate parts, creating JAMMEX, standardizing AM part numbers, and purchasing AM equipment and materials. The DLA is working with a contractor to develop prototype software that will determine if a part could be produced using AM. According to a DLA official, the software uses parts data from six data sources, and includes such data as type of material, dimensions, production lead time, and historical cost. The software enables the user to run queries to identify the potential candidate parts that meet specific criteria. When the software becomes operational, the DLA can run queries for each of the Military Services and provide a list of potential candidate parts for consideration. In addition, the DLA is creating JAMMEX, which will enable the Military Services to share technical data. According to a DLA official, JAMMEX will allow users to search any connected repository for AM parts data. The DLA is also part of a committee, along with the Military Services, that is responsible for standardizing part numbers. Finally, DLA Troop Support procured AM equipment and materials for 25 Military Service locations.

DoD Opportunities for Improvement

Despite the DoD's progress, it could increase its use of AM to obtain sustainment parts. The OSD's efforts to implement AM policy and lead a coordinated DoD-wide approach are still in the early stages. Although AM has been widely used in the DoD's maintenance and sustainment enterprise for more than 15 years, DoD-wide interim policy was not issued until March 2019. Therefore, each of the Military Services and the DLA developed their own processes, procedures, and systems to use AM. This decentralized approach led to an absence of visibility and awareness by the Military Services and the DLA about the DoD's AM capabilities and initiatives. However, the DoD could expand the use of AM by standardizing data, reporting requirements, and cataloging; sharing AM parts data; increasing workforce awareness; and identifying staff and funding needs to accomplish AM initiatives.

Standardization Needed in Data, Reporting Requirements, and Cataloging

The DoD has not standardized the data elements captured for AM parts produced to ensure consistency in production, reporting requirements for AM equipment and funds spent to understand where the DoD is investing its resources, and cataloging of AM parts to ensure the AM data are consistent and complete. The Military Services have been using AM for more than 15 years without OSD policy. USD(A&S) issued interim policy for AM in March 2019, which defined the roles and responsibilities of the Military Services and the DLA. The interim policy states that the USD(A&S) plans to finalize this policy in a DoD Instruction in 2020. In addition, the Navy drafted and is coordinating an AM Contracting and Acquisition Guide with the OSD, the Military Services, and the DLA. According to a Naval Supply Systems Command official, the Navy planned to issue the guide in September 2019. The AM Contracting and Acquisition Guide will include guidance on topics such as AM standards, intellectual property, and acquisition and contracting. According to a USD(A&S) official, the guide will be implemented across the DoD. Although the DoD has written policy that assigns responsibilities for AM and the Navy is drafting a contracting guide, neither the policy nor the guide will standardize the data elements captured for AM parts produced, reporting requirements for AM equipment and funds spent, or cataloging of AM parts.

The Military Services have been using AM for more than 15 years without OSD policy.

Standardizing Additive Manufacturing Data and Reporting Requirements

DoD policy does not identify the data that should be reported for AM parts produced, AM equipment purchased, and funds spent on AM. For example, the policy does not direct which data elements should be shared between the Military Services and the DLA. The Air Force does not include the national stock number or part number when tracking the parts produced using AM, while the Army includes this information in the Repository of Additive Parts for Tactical and Operational Readiness and NAVAIR includes this information in JTDI.[10] In addition, NAVAIR does not include the material used, but the Air Force does. Furthermore, there is no guidance on the data elements the Military Services should identify within AM technical data packages, such as the material needed to produce the part. Standardized data elements will allow the Military Services or a contractor to produce the part consistently. The USD(R&E), with input from the Military Services, should standardize the minimum data elements required to be reported by the Military Services for AM parts produced, including such elements as national stock number, weapons system, and material used.

In addition, DoD policy does not standardize the requirements for tracking AM equipment purchased by the Military Services. The Navy and Marine Corps issued policy to track all AM equipment purchased regardless of cost, while Air Force policy requires organizations to track only AM equipment costing over $100,000. The Army has policy for tracking Army-owned equipment; however, according to an Army Materiel Command official, a list of Army-owned AM equipment is not readily available and the Army Materiel Command has an outstanding data request to Army units for this information. As of June 2019, the Army Materiel Command is still waiting for this data. Standardized equipment data will allow the Military Services to be aware of the location and type of AM equipment available. Knowing the nearest location of AM equipment available to produce a part could increase the likelihood that a unit uses AM to produce a part, which would reduce the cost and time for repairing some unusable equipment. The USD(R&E) should standardize the minimum data elements required to be reported by the Military Services for tracking AM equipment, including such elements as type, cost, and location.

Finally, the DoD's interim policy does not standardize the requirements for tracking the funds spent on AM. The JAMSG required the Military Services and the DLA to report how much has been spent on AM in FY 2019. However, the JAMSG did not identify the categories of information that should be included in the amount spent, such as research and development, training, personnel, equipment, or

[10] A national stock number is a 13-digit stock number used to identify inventory items in the DoD supply system.

material. To have complete, consistent, and accurate information, the USD(R&E) should standardize the minimum data elements required when the Military Services and the DLA report the amount spent on AM, including such elements as training, personnel, and equipment. The funding information will allow the DoD to determine where it is investing its resources.

Standardizing the Cataloging of Additively Manufactured Parts

DoD policy does not establish standardized requirements for cataloging AM parts. For example, NAVAIR is adding "AM" within the traditionally manufactured part number to indicate it was manufactured using AM, while the Air Force Life Cycle Management Center is creating a new part number for parts manufactured using AM. The DLA, Military Services, and other Federal agencies, such as the General Services Administration, have representatives on the Federal Cataloging Committee. This committee is determining if AM parts should have a standardized part number or the same part number as a traditionally manufactured part. According to a DLA official, the Federal Cataloging Committee will make a recommendation to the Integrated Material Management Committee, which is responsible for Federal cataloging policy. As of June 2019, the Federal Cataloging Committee had not made its recommendation. Standardizing the cataloging of AM parts could enable the DoD to differentiate between parts produced by AM and parts produced by traditional manufacturing. The OSD should develop policy that standardizes the cataloging of AM parts and update the policy as necessary after the Integrated Material Management Committee's decision.

Method Needed to Share Data on Additively Manufactured Parts Across Military Services and the DLA

The DoD has not implemented a method for sharing AM parts data to eliminate duplicative efforts when designing and producing AM parts. Each Military Service is using multiple methods that do not interface to track and store AM part information. For example, the Navy uses JTDI, Excel spreadsheets, and an Access database to track AM parts produced or parts waiting for approval. Similarly, the Air Force is using an Access database and Excel spreadsheets to track AM parts produced or waiting for approval. Therefore, the Military Services cannot identify or share AM parts produced or parts waiting for approval, and they do not have complete visibility of the parts within each Military Service. For example, according to a Chief of Naval Operations official, the Navy is not uploading all of its locally stored data on AM parts produced into JTDI because it is waiting to upload the data into JAMMEX. Additionally, according to an

Each Military Service is using multiple methods that do not interface to track and store AM part information.

Air Force REACT laboratory official, not all AM parts produced were uploaded into the Air Force repository because of the time required to upload the large number of AM parts. The Military Services could duplicate efforts for AM-produced parts and may waste funds and time because they are not sharing information both with each other and within their own Service. For example, both the Air Force and the Navy are using AM to produce parts and tools to sustain the C-130 Hercules aircraft (C-130). By not sharing information regarding the design, type of material used, and other technical data, both Military Services could be working on the development of the same part or developing a part that has previously been engineered by the other Military Service. The Military Service AM leads should implement a process that compiles a complete list of all AM-produced parts and parts waiting for approval to share within each Military Service and update the list as needed.

In November 2018, the OSD provided funds and requirements to America Makes to develop a method for sharing AM data. The DLA has since collaborated with America Makes to develop JAMMEX, a digital exchange between Military Service data repositories. JAMMEX will be a platform for users to share approved AM technical data. As of May 2019, the DLA had not decided which Military Service data repositories will link to JAMMEX. JAMMEX was expected to be initially released and tested in August 2019, with additional development expected in 2020 that will integrate JAMMEX with other data files and expand capabilities based on user feedback. According to America Makes officials, once operational, JAMMEX should allow the Military Services and the DLA to identify and share AM parts produced and waiting for approval. The DLA will be responsible for JAMMEX updates and funding in 2020.

The Military Services and the DLA may be duplicating efforts and wasting funds by not having a single method that includes all AM parts. As AM advances, a single method for sharing and tracking part demand could eliminate duplicative AM efforts and result in cost savings throughout the DoD. The OSD should develop and require the Military Services and the DLA to use a single method to share data on AM parts.

Awareness of Additive Manufacturing Capabilities Necessary Across Functional Areas

The DoD has not increased awareness of AM capabilities among acquisition, contracting, logistics, and senior management officials to identify additional AM candidate parts through either training or guidance. For example, during our February 2019 meeting with the Air Force Materiel Command, an official expressed concern over a low-quantity, high-cost aircraft part. Prior to this meeting, the

Air Force Materiel Command official was not aware that the Air Force had the capability to potentially produce the part using AM. As a result, the Air Force Materiel Command official provided a list of over 100 aircraft parts to Air Force engineers. Within weeks, Air Force engineers began working to produce the first AM part on the list.

The OSD, the Military Services, and the DLA recognize the importance of training to foster the development, use, and implementation of AM. DoD interim AM policy requires the USD(A&S) to incorporate AM into training for the acquisition and sustainment workforce. The policy also requires Military Service Secretaries to certify that personnel involved with AM acquisition or manufacturing are adequately trained on AM processes. As of May 2019, the Military Services' AM guidance did not require contracting, acquisition, logistics, and senior management officials to obtain AM training.

The Navy is developing an AM Contracting and Acquisition Guide that should be helpful to the contracting and acquisition community if adopted across the DoD. While the guide will be helpful, the OSD should inform the Military Services and DLA program officers, logisticians, contracting officers, and senior DoD management about AM and about updates to the DoD's AM capabilities as those capabilities advance. The OSD should also require the Military Services and the DLA to update their AM guidance.

Staffing and Funding Needed to Support Additive Manufacturing Initiatives

The DoD has not identified the staffing and funding necessary to accomplish AM initiatives. In July 2017, the USD for Acquisition, Technology, and Logistics stated that the DoD needed to implement AM across the DoD and the NDAA for FY 2017 Senate Report "strongly encouraged" the use of AM. In addition, each Military Service has an AM plan that assigns responsibilities for implementing AM initiatives; however, according to the implementing office officials, they have not identified a budget with the estimated costs and staff needed to meet these requirements. For example, the Army's AM plan has 5 initiatives to implement AM capabilities that require participation on 13 working groups from 11 Army organizations. However, Army Combat Capabilities Development Command officials said that they were not aware of an Army budget with estimated costs for these efforts. The audit team asked for the Army's AM funding requirements, but the Army Materiel Command did not provide it. In contrast, DLA Headquarters provided an initial estimate identifying the need for fully dedicated staff to meet its requirements and timelines.

In addition, according to NAVSEA, Air Force Life Cycle Materiel Command, Marine Corps Logistics Command, and DLA officials, the DoD will need additional engineers to keep up with the predicted demand and certification of AM parts. Each AM candidate part needs to be approved by an engineer prior to being produced to ensure the part meets military specifications. However, the Military Services have not identified the number of additional staff necessary to support the approval of candidate parts.

It is necessary to identify the staffing and funding the OSD and the Military Services will need to continue their involvement with working groups, prepare plans and policies, and quickly review and approve the use of additional AM parts. Therefore, OSD and Military Service personnel should conduct a review to identify the appropriate funding and number of engineers, operators, or other personnel to pursue benefits of AM throughout the DoD.

Accelerating the Use of Additive Manufacturing Could Save Funds and Improve Readiness

The DoD could expand the use of AM by standardizing requirements, sharing AM parts data, increasing workforce awareness, and identifying staff and funding needs. These actions could increase the use of AM and improve warfighter readiness by decreasing the lead and repair times from years to days for some hard-to-procure parts that can be produced through AM. For example, by using AM to produce a MH-60R sonar system cover, the Navy reduced the time it took to receive the part from 2 years to 1 week. In addition, the DoD could realize cost savings by eliminating duplicative AM efforts. For example, the Military Services are not sharing information on AM parts. A DoD joint method for sharing data will allow the Military Services to view and use each other's technical data and progress on AM parts produced and waiting for approval. The DoD could also realize cost savings by using AM to produce low-quantity and high-cost parts that are hard to obtain or to replace a single part rather than an entire component if the part is found to be appropriate for AM. For example, the Navy used AM to produce an F-35 Joint Strike Fighter (F-35) landing gear door bump stop for $0.75. The bump stop was not available for individual purchase and had to be purchased as part of the landing gear assembly for $70,000. The AM-produced part made it unnecessary for the Navy to purchase the entire assembly. Figure 8 shows AM-produced and traditionally manufactured bump stops.

By using AM to produce a MH-60R sonar system cover, the Navy reduced the time it took to receive the part from 2 years to 1 week.

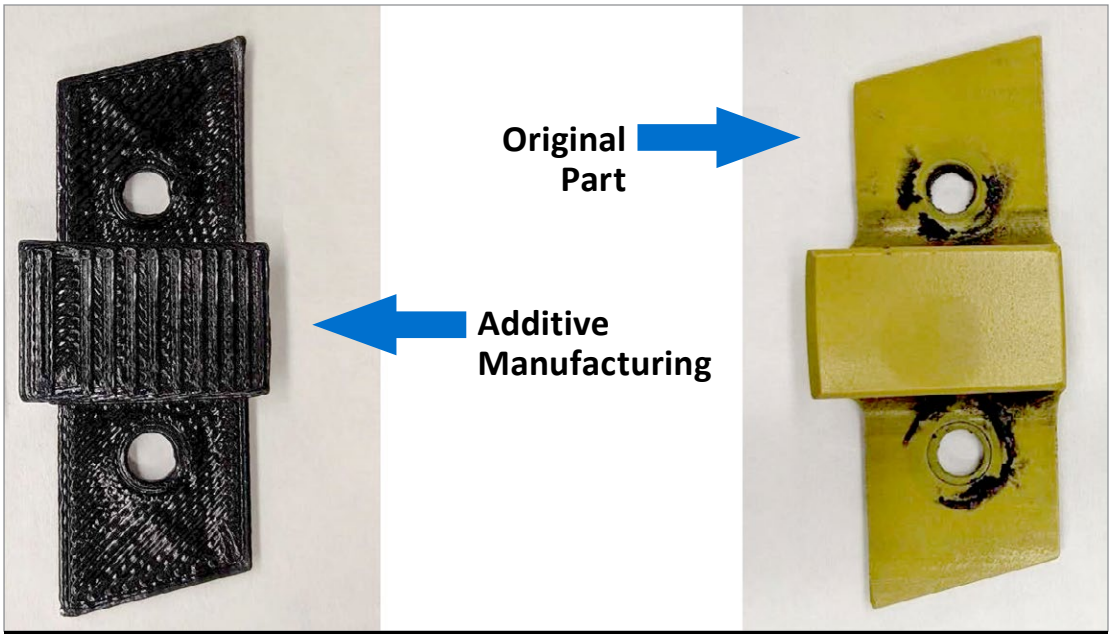


Figure 8. Traditionally and AM Produced Bump Stops for F-35B Landing Gear Door
Source: The Marine Corps.

Recommendations, Management Comments, and Our Response

Recommendation 1

We recommend that the Under Secretary of Defense for Research and Engineering standardize the data to be reported by the:

a. Military Services for parts produced using additive manufacturing and additive manufacturing equipment.

b. Military Services and Defense Logistics Agency for the amount spent on additive manufacturing.

Management Comments Required

The Under Secretary of Defense for Research and Engineering did not respond to the recommendation in the report. Therefore, the recommendation is unresolved. We request that the Under Secretary provide comments on the final report.

Recommendation 2

We recommend that the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment:

a. Develop policy that standardizes the cataloging of additively manufactured parts and update the policy as necessary after the Integrated Material Management Committee's decision.

b. Develop and require the Military Services and the Defense Logistics Agency to use a single method to share data on additively manufactured parts.

c. Inform the Military Services and the Defense Logistics Agency program officers, logisticians, contracting officers, and senior DoD management about additive manufacturing and about updates to the DoD's additive manufacturing capabilities.

d. Require the Military Services and the Defense Logistics Agency to update their additive manufacturing guidance to require contracting, acquisition, logistics, and senior management officials to obtain AM training.

Management Comments Required

The Under Secretary of Defense for Research and Engineering and the Under Secretary of Defense for Acquisition and Sustainment did not respond to the recommendations in the report. Therefore, the recommendations are unresolved. We request that the Under Secretaries provide comments on the final report.

Recommendation 3

We recommend that the Military Service Secretaries and the Marine Corps Commandant require the additive manufacturing leads to implement a process that compiles a complete list of all parts produced using additive manufacturing and parts waiting for approval to share within each Military Service and update the list as needed.

Secretary of the Navy Comments

The Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation), on behalf of the Secretary of the Navy, agreed, stating that the Navy implemented a process in 2018 to capture and compile lists of AM parts at the Navy Systems Command level. The AM parts lists are briefed quarterly to the Naval AM Executive Committee. The Navy is working to make these parts accessible and has uploaded completed technical data into JTDI. Once JAMMEX is released and fully functional, the AM parts will be linked to JAMMEX and accessible to the other Services.

Secretary of the Air Force Comments

The Assistant Secretary of the Air Force (Acquisition, Technology and Logistics), on behalf of the Secretary of the Air Force, agreed, stating that the Air Force Metals Technology Office within the Air Force Life Cycle Management Center, Product Support Engineering Division, distributed an AM Developmental Guidance Notification to Air Force users. This notification prescribes the approval process for AM parts and the requirement to upload AM parts information in the Air Force Advanced Technology Training Center AM Parts Tracker database. In addition, JAMMEX is intended to enable connection of the Services databases after transition of the tool to the DLA in FY 2020.

Marine Corps Commandant Comments

The Headquarters, Marine Corps Deputy Commandant for Installations and Logistics, on behalf of the Marine Corps Commandant, agreed, stating that the Marine Corps implemented a process in 2016 to capture and compile lists of AM parts at the Marine Corps Systems Command level. The Marine Corps currently uses Marine Maker to store and share parts produced, but will transition to a new digital repository in the first quarter of FY 2020. Once JAMMEX is released and fully functional, the AM parts will be linked to JAMMEX and accessible to the other Services. The Marine Corps is also working to refine the requirements for the Digital Management Data Vault, which is a product life-cycle management-based repository. The Digital Management Data Vault will integrate AM data with program-managed technical data and be compatible with JAMMEX. The Digital Management Data Vault is planned for fielding during FY 2024.

Our Response

Comments from the Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation); Assistant Secretary of the Air Force (Acquisition, Technology and Logistics); and Headquarters, Marine Corps Deputy Commandant for Installations and Logistics addressed the specifics of the recommendation. Therefore, the recommendation is resolved but will remain open. We will close this recommendation once the Navy, Air Force, and Marine Corps provide documentation verifying they have compiled complete and accessible lists of the parts produced and parts awaiting approval.

Management Comments Required

The Secretary of the Army did not respond to the recommendation in the report. Therefore, the recommendation is unresolved. We request that the Secretary of the Army provide comments on the final report.

Recommendation 4

We recommend that the Under Secretary of Defense for Research and Engineering, Under Secretary of Defense for Acquisition and Sustainment, Military Service Secretaries, and the Marine Corps Commandant conduct a review to identify the appropriate funding and number of personnel to pursue benefits of additive manufacturing throughout the DoD.

Secretary of the Navy Comments

The Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation), on behalf of the Secretary of the Navy, agreed, stating that the Naval AM Executive Committee has scoped and prioritized enterprise-wide AM implementation efforts and identified primary areas to address hurdles to widespread AM adoption. The Naval AM Executive Committee also identified specific tasks to be assigned to the relevant stakeholders within the Navy Systems Commands. These tasks have provided the Navy the ability to determine the appropriate funding and staffing levels for each Navy Systems Command. The primary areas were funded over multiple years to address foundational AM development.

Secretary of the Air Force Comments

The Assistant Secretary of the Air Force (Acquisition, Technology and Logistics), on behalf of the Secretary of the Air Force, agreed, stating that the Secretary of the Air Force, Logistics and Product Support, will partner with the Air Force Materiel Command to review and identify the appropriate funding and number of personnel required to fully integrate AM throughout the Air Force by March 15, 2020.

Marine Corps Commandant Comments

The Headquarters, Marine Corps Deputy Commandant for Installations and Logistics, on behalf of the Marine Corps Commandant, agreed, stating that the Marine Corps has two fully funded Programs of Record, which will result in issuing AM capabilities to over 200 units across the Marine Corps during FY 2025. The Marine Corps will release an enterprise-wide policy on AM during the first quarter of FY 2020. The policy will outline specific processes and tasks to identify appropriate funding and personnel as well as to continue to enhance and mature AM throughout the Marine Corps.

Our Response

Comments from the Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation); Assistant Secretary of the Air Force (Acquisition, Technology and Logistics); and Headquarters, Marine Corps Deputy Commandant for Installations and Logistics addressed the specifics of the recommendation. Therefore, the recommendation is resolved but will remain open. We will close this recommendation once the Navy, Air Force, and Marine Corps provide documentation verifying they have developed an estimate of the appropriate funding and staffing levels.

Management Comments Required

The Under Secretary of Defense for Research and Engineering, Under Secretary of Defense for Acquisition and Sustainment, and Secretary of the Army did not respond to the recommendation in the report. Therefore, the recommendation is unresolved. We request that the Under Secretary of Defense for Research and Engineering, Under Secretary of Defense for Acquisition and Sustainment, and Secretary of the Army provide comments on the final report.

Appendix

Scope and Methodology

We conducted this performance audit from November 2018 through August 2019 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.

Additive Manufacturing Stakeholders

To determine the extent the DoD is using AM for sustainment parts, we interviewed AM leads, engineers, program office and contracting officials, and AM equipment operators from the following offices to identify roles and responsibilities.

- USD(A&S)
- USD(R&E)
- Deputy Assistant Secretary of the Navy for Research Development Test and Evaluation
- Chief of Naval Operations for Fleet Readiness and Logistics
- NAVAIR
- NAVSEA
- Naval Supply Systems Command
- Space and Naval Warfare Systems Command
- Naval Fleet Readiness Center Southwest
- Office of Naval Research
- Headquarters, Marine Corps Aviation
- Headquarters, Marine Corps Installations and Logistics
- Marine Corps Systems Command
- Marine Corps Logistics Command
- I Marine Expeditionary Force
- Marine Corps Air Ground Combat Center Fabrication Laboratory
- Assistant Secretary of the Army (Acquisition, Logistics and Technology)
- Army Materiel Command
- Army Deputy Chief of Staff for Logistics

- Army Contracting Command
- Army Training and Doctrine Command
- Army Aviation and Missile Command Logistics Center
- Rapid Fabrication Laboratory, Camp Humphreys, South Korea
- Army Combat Capabilities Development Command Armament Center
- Army Combat Capabilities Development Command Aviation and Missile Center
- Secretary of the Air Force for Acquisition
- Air Force Materiel Command
- Air Force Life Cycle Management Center
- Air Force Research Laboratory
- Air Force Sustainment Center
- DLA Headquarters
- DLA Aviation
- DLA Troop Support
- Defense Contract Management Agency
- Defense Acquisition University
- America Makes

Determining the Extent Additive Manufacturing Was Used

To determine the extent that the DoD is using AM for sustainment parts, we obtained information on the number of AM parts approved, produced, or waiting for approval contained in tracking tools, such as data repositories or Excel spreadsheets. However, the Military Services were unable to provide the exact number of parts approved, produced, or waiting for approval. We also reviewed documentation and interviewed officials to determine if the tracking tools interfaced with each other.

We interviewed Military Service and DLA officials and obtained DoD and Military Service-level policies to determine whether there are standard processes the Military Services and the DLA had to follow when reporting information about using or funding AM, cataloging parts, or contracting for an AM part.[11] We also reviewed policies and guidance to determine whether end users, contracting officials, and program officials were required to consider using AM when

[11] The Military Services have not contracted for sustainment parts produced using AM. However, the DLA awarded one contract for a part that was produced using AM, but did not include the use of AM in the contract language.

obtaining sustainment parts. In addition, we interviewed AM leads in the Military Services and the DLA, engineers, program office and contracting officials, and AM equipment operators to determine whether they used AM or had received formal training on AM.

Finally, we interviewed OSD, Military Service, and DLA officials to determine the number of staff dedicated to fulfilling AM requirements. We obtained documentation on funding spent for AM personnel, equipment, material, and software and we requested staffing plans and budgetary documentation.

Additive Manufacturing Guidance

We reviewed the following guidance related to AM.

- USD(A&S), Directive-Type Memorandum-19-006, "Interim Policy and Guidance for the Use of AM in Support of Materiel Sustainment," March 21, 2019
- Headquarters Department of the Army Execution Order 050-18, "Guidance for the Use of AM Equipment and Software," December 2017
- Secretary of the Navy Memorandum, "AM/3D Printing," September 3, 2015
- NAVSEA Message, "Issuing of Guidance on the Use of AM," September 11, 2018
- NAVSEA, "Policy on the Use of AM," January 12, 2015
- NAVSEA Letter 4870, "Guidance on the Use of AM," August 17, 2018
- NAVAIR Message, "Interim Guidance to Request and Employ AM Technologies Components on Naval Aircraft and Associated Equipment," March 14, 2018
- Deputy Chief of Naval Operations Naval Administrative Message 309/17, "AM - A Challenge for Every Sailor," December 22, 2017
- Draft Secretary of the Navy Policy Letter, "AM," as of November 5, 2018
- Marine Administration Message Number 489/16, "Interim Policy on the Use of AM (3D Printing) in the Marine Corps," September 16, 2016
- Marine Administration Message Number 594/17, "Headquarters Marine Corps Procedural Guidance Update on the Management and Employment of AM," October 25, 2017
- Marine Administration Message Number 209/18, "Interim Policy on the Use of AM (3D Printing) in Marine Aviation," April 12, 2018
- Marine Administration Message Number 055/19, "Headquarters Marine Corps Procedural Guidance Update Number Two on the Management and Employment of AM," January 30, 2019

Use of Computer-Processed Data

We did not use computer-processed data to perform this audit.

Prior Coverage

During the last 5 years, the GAO issued two reports discussing AM. Unrestricted GAO reports can be accessed at http://www.gao.gov.

GAO

GAO-16-56, "DoD Needs to Systematically Track Department-wide 3D Printing Efforts," October 2015

> This report identified that the DoD has taken steps to implement AM to improve performance and combat capability, and to achieve cost savings. The GAO also identified that the DoD uses various mechanisms to coordinate AM efforts. However, the DoD does not systematically track Components' efforts DoD-wide, to include all activities performed and resources expended by the DoD and the results of these activities, including actual and potential performance and combat capability improvements, cost savings, and lessons learned.

GAO-15-505SP, Highlights of a Forum presented to the Chairman, Committee on Science, Space, and Technology, House of Representatives, "3D Printing: Opportunities, Challenges, and Policy Implications of AM," June 2015

> This report identified that the DoD is looking at ways to use AM in supply chain management, including to repair equipment and produce parts in the field, to reduce the need to store parts, to produce discontinued parts or temporary parts to use until a permanent part can be obtained, and to quickly build parts to meet mission requirements.

Management Comments

Office of the Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation)

DEPARTMENT OF THE NAVY
OFFICE OF THE ASSISTANT SECRETARY
RESEARCH, DEVELOPMENT AND ACQUISITION
1000 NAVY PENTAGON
WASHINGTON DC 20350-1000

SEP 2 7 2019

MEMORANDUM FOR PROGRAM DIRECTOR FOR AUDIT, ACQUISITION, CONTRACTING AND SUSTAINMENT, DEPARTMENT OF DEFENSE INSPECTOR GENERAL
(ATTN: [redacted])

SUBJECT: Navy response to the Department of Defense (DoD) Inspector General Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts (Project No. D2019-D000AT-0057.000)

Additive Manufacturing (AM) is a cross-cutting technology with significant implications for the U.S. manufacturing base and naval warfare. It can shorten the design to production cycle, enable new designs and facilitate cost effective on-demand manufacturing.

Below you will find the Department of the Navy's (DON) responses to the recommendations from the Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts Report.

Recommendation 1:
We recommend that the Under Secretary of Defense for Research and Engineering standardize the data to be reported by the:

1.a. Military Services for parts produced using additive manufacturing and additive manufacturing equipment.

1.b. Military Services and Defense Logistics Agency for the amount spent on additive manufacturing.

Response:
This recommendation is directed to the Under Secretary of Defense for Research and Engineering (USD(R&E)) and Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)), the Department of the Navy defers to their response on this specific recommendation.

Recommendation 2:
We recommend that the Under Secretary of Defense for Research and Engineering, in coordination with the Under Secretary of Defense for Acquisition and Sustainment:

Office of the Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation) (cont'd)

SUBJECT: Navy response to the Department of Defense (DoD) Inspector General Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts (Project No. D2019-D000AT-0057.000)

2.a. Develop policy that standardizes the cataloging of additively manufactured parts and update the policy as necessary after the Integrated Material Management Committee's decision.

2.b. Develop and require the Military Services and the Defense Logistics Agency to use a single method to share data on additively manufactured parts.

2.c. Inform the Military Services and the Defense Logistics Agency program officers, logisticians, contracting officers, and senior DoD management about additive manufacturing and about updates to the DoD's additive manufacturing capabilities.

2.d. Require the Military Services and the Defense Logistics Agency to update their additive manufacturing guidance to require contracting, acquisition, logistics, and senior management officials to obtain AM training.

Response:
This recommendation is directed to the Under Secretary of Defense for Research and Engineering (USD(R&E)) and Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)), the Department of the Navy defers to their response on this specific recommendation.

Recommendation 3:
We recommend that the Military Service secretaries and the Marine Corps Commandant require the additive manufacturing leads to implement a process that compiles the complete list of all parts produced using additive manufacturing and parts waiting for approval to share with each Military Service and update the list as needed.

Response:
Concur. The Navy implemented a process in 2018 to capture and compile lists of additively manufactured parts at the Navy Systems Command (SYSCOM) level. AM part lists are maintained by the SYSCOMs and briefed quarterly to the Naval Additive Manufacturing (AM) Executive Committee (EXCOMM). These lists are part of a broader "metrics" collection effort, including time from request to "triage", time from "triage" to print, and how parts are binned based on a risk, material, process maturity, etc. The DON is working to make these parts accessible, and has uploaded completed Technical Data Packages (TDP) to a NAVAIR Joint Technical Data Integration (JTDI) site. Once the OSD Joint Additive Manufacturing Model Exchange (JAMMEX) is released and fully functional these parts will be linked to JAMMEX and visible/accessible to other Services.

2

Office of the Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation) (cont'd)

SUBJECT: Navy response to the Department of Defense (DoD) Inspector General Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts (Project No. D2019-D000AT-0057.000)

Recommendation 4:
We recommend that the Under Secretary of Defense for Research and Engineering (USD(R&E)), Under Secretary of Defense for Acquisition and Sustainment (USD(A&S)), Military Service Secretaries, and the Marine Corps Commandant conduct a review to identify the appropriate funding and number of personnel to pursue benefits of additive manufacturing throughout the DoD.

Response:
Concur. The Naval AM EXCOMM, via the Department of the Navy AM Implementation Plan V2.0 (2017), has scoped and prioritized enterprise-wide AM implementation efforts using primary thrust areas aimed at addressing the most significant hurdles to wide-spread AM adoption and operationalization. Within each of the thrust areas, specific tasks have been broken out and assigned to the relevant stakeholder(s) within the Navy SYSCOMS. These tasks have provided the Navy the ability to determine the appropriate funding and staffing levels for each SYSCOM. The established aggressive thrust areas address the overall findings of the subject audit and enhance the Navy's ability to obtain sustainment parts. The thrust areas were funded over multiple years to address foundational AM development:

1) Develop AM standards, technical data packages (TDP's) and a common Service material database;
2) Establish a digital ecosystem to include methods for sharing files across the Navy and Marine Corps as well as outside organizations to encourage sharing and use to the greatest extent possible and eliminate duplicative efforts;
3) Expand expeditionary and afloat capabilities to include deployment of fabrication labs aboard ships;
4) Develop the workforce including funded efforts for an apprentice/journeyman certification program through America Makes;
5) Develop business practices including an acquisition guide and cataloguing of end use parts.

3

Office of the Deputy Assistant Secretary of the Navy (Research, Development, Test and Evaluation) (cont'd)

SUBJECT: Navy response to the Department of Defense (DoD) Inspector General Audit of the DoD's Use of Additive Manufacturing for Sustainment Parts (Project No. D2019-D000AT-0057.000)

Thank you for the opportunity to respond to these recommendations. If you require any additional information, please contact [redacted] AM Implementation Lead DASN RDT&E.

William P. Bray
Deputy Assistant Secretary of the Navy
(Research, Development, Test & Evaluation)

Attachments:
As stated

cc:
DASN (M&B)

4

Office of the Assistant Secretary of the Air Force (Acquisition, Technology and Logistics)

DEPARTMENT OF THE AIR FORCE
WASHINGTON, DC

OFFICE OF THE ASSISTANT SECRETARY

03 OCT 2019

MEMORANDUM FOR DEPARTMENT OF DEFENSE INSPECTOR GENERAL

FROM: SAF/AQ

SUBJECT: Air Force Response to DoD Office of Inspector General Draft Report, *Audit of 103104the DOD's Use of Additive Manufacturing for Sustainment Parts* (Project No. D2019-D000AT-0057.000)

SAF/AQ concurs with the DoDIG Draft Report, *Audit of the DOD's Use of Additive Manufacturing for Sustainment Parts* (Project No. D2019-D000AT-0057.000), as written and welcomes the opportunity to partner with OSD and the other Services to optimize utilization of Additive Manufacturing (AM) to improve warfighter readiness, reduce cost, and transform the Air Force's maintenance and supply chain activities.

SAF/AQ in coordination with AFMC will correct issues identified in this report, develop and implement a corrective action plan outlined in the following recommendations:

RECOMMENDATION 3: The DODIG recommends that the Air Force "require the additive manufacturing leads to implement a process that compiles a complete list of all parts produced using additive manufacturing and parts waiting for approval to share within each Military Service and update the list as needed".

AIR FORCE RESPONSE: Concur: The Air Force Life Cycle Management Center, Product Support Engineering Division, is the Air Force lead for AM implementation. The Air Force Metals Technology Office falls within the Product Support Engineering Division. This office distributed an AM Developmental Guidance Notification (attached). It prescribes the approval process for AM parts and the requirement to upload AM parts information on the Air Force Advanced Technology Training Center AM Parts Tracker data base. In addition, OUSD supports initial development of the Joint Additive Manufacturing Exchange (JAMMEX) and intends to enable connection of the Services databases after transition of the tool to DLA in FY20. ECD: 15 March 2020

RECOMMENDATION 4: The DoDIG recommends that the Air Force "conduct a review to identify the appropriate funding and number of personnel to pursue benefits of additive manufacturing throughout the DoD".

AIR FORCE RESPONSE: Concur: The Air Force recognizes AM as game changing technology, can improve war fighter readiness, and drive down sustainment costs. SAF/AQD will partner with AFMC to review and identify appropriate funding and number of personnel required to fully integrate additive

Office of the Assistant Secretary of the Air Force (Acquisition, Technology and Logistics) (cont'd)

manufacturing throughout the Air Force. ECD: 15 March 2020

The Air Force point of contact is [redacted] or via email at [redacted]

William B. Roper, Jr.
Assistant Secretary of the Air Force
(Acquisition, Technology & Logistics)

Attachment:
Air Force Metals Technology Office (AF MTO) Additive Manufacturing (AM) Developmental Guidance Notification: 19-003, *Additive Manufacturing Request Form and Parts Tracker*

2

Headquarters, United States Marine Corps

DEPARTMENT OF THE NAVY
HEADQUARTERS, UNITED STATES MARINE CORPS
3000 MARINE CORPS PENTAGON
WASHINGTON, DC 20350-3000

IN REPLY REFER TO:
7500
DMCS-A
2 Oct 19

From: Head, Audit Coordination and Liaison, Office of the Director, Marine Corps Staff
To: Program Director, Acquisition, Contracting, and Sustainment Audits, Office of Inspector General, U.S. Department of Defense

Subj: AUDIT OF THE DOD'S USE OF ADDITIVE MANUFACTURING FOR SUSTAINMENT PARTS (DODIG OFFICIAL DRAFT AUDIT REPORT PROJECT NO. D2019-D000AT-0057.000 DATED AUGUST 27, 2019)

Ref: (a) DODIG Memorandum on subject dated August 27, 2019

Encl: (1) Deputy Commandant for Installations and Logistics Responses

1. Reference (a) provided the subject audit report for review and comment.

2. Responding for the Commandant of the Marine Corps, enclosure (1) provides official responses from the Headquarters, U.S. Marine Corps Deputy Commandant for Installations and Logistics.

3. We appreciate the opportunity to respond to the report.

4. For questions regarding the enclosure, I can be reached at [redacted].

CHARLES K. DOVE

Copy to:
NAVAUDSVC
NAVINSGEN (N14)
IGMC
CL
DC, P&R (MCMICP)
DC, I&L
DC, CD&I
DC, AVN
CMDR, MCSC
CMDR, MCLC

Headquarters, United States Marine Corps (cont'd)

DEPARTMENT OF DEFENSE INSPECTOR GENERAL (DODIG)
DRAFT REPORT DATED 27 AUGUST 2019
PROJECT # D2019-D000AT-0057.000

"AUDIT OF THE DOD'S USE OF ADDITIVE MANUFACTURING FOR SUSTAINMENT PARTS"

UNITED STATES MARINE CORPS COMMENTS
TO THE DODIG RECOMMENDATIONS

RECOMMENDATION 3: DODIG recommends that the Military Service Secretaries and the Marine Corps Commandant require the additive manufacturing leads to implement a process that compiles a complete list of all parts produced using additive manufacturing and parts waiting for approval to share within each Military Service and update the list as needed.

USMC RESPONSE: The Deputy Commandant for Installations and Logistics, responding for the Commandant of the Marine Corps, concurs with recommendation 3. The Marine Corps implemented a process in 2016 to capture and compile a complete list of Additive Manufacturing (AM) parts at the Marine Corps Systems Command-level. The AM parts list is maintained by Marine Corps Systems Command (MCSC) and files can be accessed via an online digital repository. MCSC currently uses *Marine Maker*, an internet based repository, to store and share all AM parts produced by Marines for ground vehicles. Additionally, MCSC records and tracks approval of all AM parts for ground equipment that require Program Manager approval. In 1st Quarter FY20, MCSC will transition online functions to *8 Wire*, a new repository with enhanced functionality for ease of use, and eventual integration with the OSD Joint Services Additive Manufacturing Model Exchange (JAMMEX). Maintaining the AM parts list is part of a broader Marine Corps "metrics" collection effort, including time from request to "triage", time from "triage" to print, and how parts are binned based on risk, material, process maturity, etc. The Marine Corps has also incorporated AM into the Marine Corps Global Combat Support System (GCSS), which allows for not only the tracking of individual parts printed but also the time and material used to print each part. Once the OSD JAMMEX is released and fully functional, AM parts will be linked to JAMMEX and visible/accessible to other Services; this is expected to occur during 2nd Quarter FY20. Commander MCSC is working with Deputy Commandant Installation & Logistics and Deputy Commandant Combat Development and Integration to refine the requirements for a Digital Management Data Vault (DMDV), a Product Life-Cycle Management based, JAMMEX compatible repository designed to seamlessly integrate AM data with all program managed technical data. The DMDV solution is planned for fielding during fiscal year 2024.

Enclosure (1)

Headquarters, United States Marine Corps (cont'd)

SUBJ: USMC COMMENTS TO DODIG REPORT # D2019-D000AT-0057.000

RECOMMENDATION 4: DODIG recommends that the Under Secretary of Defense for Research and Engineering, Under Secretary of Defense for Acquisition and Sustainment, Military Service Secretaries, and the Marine Corps Commandant conduct a review to identify the appropriate funding and number of personnel to pursue benefits of additive manufacturing throughout the DoD.

USMC RESPONSE: The Deputy Commandant for Installations and Logistics, responding for the Commandant of the Marine Corps, concurs with recommendation 4. The Marine Corps has two fully funded Programs of Record: Expeditionary Fabrication (an intermediate level capability) and Tactical Fabrication (an organizational capability). These two Programs of Record will result in issuing Additive Manufacturing (AM) capabilities to over 200 units across the Marine Corps during fiscal year 2025. The Marine Corps will release an enterprise wide policy on AM in the form of a Marine Corps Order during 1st Quarter FY20. Within this policy, the Marine Corps has outlined specific processes and identified tasks to not only identify appropriate funding and personnel, but also establish processes and capability development to continue to enhance and mature AM throughout the Marine Corps.

2

Enclosure (1)

Acronyms and Abbreviations

AM	Additive Manufacturing
DLA	Defense Logistics Agency
GAO	Government Accountability Office
JAMMEX	Joint Additive Manufacturing Model Exchange
JAMSG	Joint Additive Manufacturing Steering Group
JTDI	Joint Technical Data Integration
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NDAA	National Defense Authorization Act
OSD	Office of the Secretary of Defense
R-FAB	Rapid Fabrication via Additive Manufacturing on the Battlefield
REACT	Reverse Engineering and Critical Tooling
USD(A&S)	Under Secretary of Defense for Acquisition and Sustainment
USD(R&E)	Under Secretary of Defense for Research and Engineering


INSPECTOR GENERAL
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