SYM-AM-17-073

Proceedings
of the
Fourteenth Annual Acquisition Research Symposium

Thursday Sessions
Volume II

Acquisition Research:
Creating Synergy for Informed Change

April 26–27, 2017

Published March 31, 2017

Prepared for the Naval Postgraduate School, Monterey, CA 93943.

Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School

Using Additive Manufacturing to Mitigate the Risks of Limited Key Ship Components of the Zumwalt-Class Destroyer

LT Xiao Y. Wang, USN

LCDR James R. Whitworth, USN

Introduction

The purpose of this project was to explore the benefits of using a combination of additive manufacturing (AM), performance-based logistics (PBL), and open systems architecture (OSA) to mitigate the risks of limited key ship components for the Zumwalt-class destroyer (DDG 1000) program. Specifically, this project was focused on current industry's capability for AM and the implementation of AM in the near future. Research was conducted in three phases. First, this research reviewed the problems and challenges within the defense industry. Next, this research reviewed the previous research on intellectual property (IP) concerns with AM (particularly, insourcing versus outsourcing) and the latest AM applications in the marketplace and defense industry. Finally, this research focused on DDG 1000 program documents, including the Acquisition Strategy (AS), the Life-Cycle Sustainment Plan (LCSP), and a Diminishing Manufacturing Sources and Material Shortages (DMSMS) analysis. By conducting a comparison of DDG 51 and DDG 1000 and analyzing an AM arrangement among Airbus, Systemanalyse and Programmentwicklung (SAP), and United Parcel Service (UPS), this research concludes that the government can use AM, with a properly structured PBL arrangement and OSA, to substantially mitigate risks, lower operation and support (O&S) costs, and effectively improve system readiness.

Zumwalt-class destroyer (DDG 1000) is a three-ship program that represents the pinnacle of state-of-the-art technology. Because of technologies, intellectual properties, and scale economies, DDG 1000 is in a sole-source, or limited sources, acquisition environment. The risks associated with a limited supplier base could threaten the part support on many key ship components and the overall performance of its service life for the next 25 years or more. For cost saving purposes, all three ships will have a homeport in San Diego, CA, where organic repair, off-ship maintenance, and performance-based logistic support take place. The DDG 1000 program is also facing budget cuts, program cost growth, and competition from other classes of ships; therefore, Program Executive Office (PEO) Ships and the DDG 1000 program office must find ways to mitigate the risks of key ship components and enhance system performance with a sound life cycle sustainment strategy.

Traditional approaches for operating and maintenance are accomplished with organic repair capabilities or contracted services. Due to the technology complexity and existing organic capabilities, a combination of organic support and performance-based logistics (PBL) has been identified as part of DDG 1000's life cycle sustainment plan. Regardless of the approaches, either the government or the chosen PBL providers will have to tackle the obsolescence issues and address the issues associated with a limited supplier base. Traditionally, the decision-maker will have to decide on either a lifetime-buy or bridge-buy decision, based on industry data and the obsolescence management forecast, and anticipate failure rates to ensure that the needed parts are available for the operation and support of the systems. The advent of additive manufacturing (AM) and recent technology advancement can eliminate the need for a lifetime or bridge-buy decision, reduce ship's operating and maintenance costs, and enhance system performance. Research on AM developments is used to identify capability gaps and explore opportunities for improving system readiness.

In order to introduce AM as part of the solution, this project first examined the benefits and limitation of PBL and assessed the competition requirement for federal acquisition strategy and the challenges in obsolescence management. This project then verified that PBL and OSA are part of DDG 1000's acquisition strategy, as they are the prerequisites for entering a contractual agreement with contracted service providers for Operation and Support (O&S) and enabling system interoperability. This project subsequently compared operating and support characteristics between Arleigh Burke–class (DDG 51) and Zumwalt-class (DDG 1000) ships and assessed the ability of the DoD to expand DDG 1000's logistic support footprint, similar to the arrangement among Airbus, Systemanalyse and Programmentwicklung (SAP), and UPS.

The purpose of the study was to research the latest AM developments within the commercial marketplace and defense industry and explore the ways that AM can help to drastically reduce the risks of limited key ship components. The project answered the following questions:

- How should the government structure PBL contracts that will incentivize the use of AM?
- If the government decides to insource, what are the considerations in make-or-buy decisions?
- How can the DDG 1000 program leverage the capabilities of AM for its existing and future requirements?

Primary research data was provided by the Zumwalt-class Program Office (PMS 500). Secondary research was collected from public resources. Based on the findings of this research, it is imperative to have AM, properly structured PBL arrangements, and well thought-out OSA strengthen each other and mitigate the risks of limited key ship components that are associated with their supplier base. Naval Undersea Warfare Center (NUWC), PMS 500, and contractors could jointly identify parts as candidates for AM solutions. PMS 500 should also engage other DoD agencies on AM capacities and request information from defense contractors on their planned use of AM capabilities for part support.

Finding 1 and Recommendations

In order to take advantage of the capabilities and potential that AM offers, the government needs to structure performance-based arrangements that will help to extract innovation, motivation, and collaboration from its contractors. As the 2016 update to the DoD PBL guidebook stated, "PBL is not a one-size fits all tool … evidence provides a compelling case that performance-based sustainment is both a successful and robust strategy" (ASD[L&MR], 2016). While PBL arrangements can transfer the risk of managing O&S to a contractor to a certain degree and insourcing can provide some assurance, PBL and insourcing can still have shortfalls.

There are additional challenges for entering a PBL relationship with commercial vendors and defense contractors with the aim of taking advantage of the most revolutionary manufacturing process. First, the government has to incorporate AM as part of its requirement, acquisition strategy, and sustainment plan. Then the government needs to solicit the ideas, offers, and solutions from the marketplace and defense industry. Since the current state of technology makes AM more ideal for low-volume and low-quantity production, the government will need to use incentives to elicit desired behaviors and extract performance outcomes. It is not as simple as increasing the profit margin and reimbursing allowable costs, but entails careful planning, analyzing, monitoring, and evaluating with adequate goals, metrics, and methodologies.

The government understands its requirements well, or at least, the quantity and the delivery schedule of the requirements, while the contractors know their capabilities better. If the government does not clearly specify the requirement of incorporating AM as part of the PBL contract, the contractor will have the ambiguity and freedom to decide how to satisfy the government's needs. Since traditional manufacturing facilities are still in use and a large order quantity provides good profit, some contractors will have less incentive to introduce AM as part of a solution and will continue to expect that a large quantity was the primary means to achieving cost savings. More importantly, it is in the government's best interest to identify AM vendors through market research as soon as practical and promote competition.

While the 2016 release of the PBL guidebook provides the DoD with the 10 tenets for PBL arrangement, the strategic considerations for IP rights, the data collection phase process, and the steps for the implementation of PBL, this project looked into the FAR and DFARS, which identified two specific incentives the government can use to elicit the desired outcomes. AM requires companies to sink substantial investments, in both resources and manpower, to keep pace with the new technologies/sub-technologies that are constantly evolving in the marketplace. At the same time, existing, traditional manufacturing facilities, resources, and processes are competing for resources and remain significant for their known advantages. Therefore, it is important to use the efficiency factor during PBL contract negotiation to spur investment in innovative manufacturing processes, particularly in AM. Also, this project shows that most of the defense contractors who aggressively pursue AM are the well-established industry giants. In order to maximize small business participation in AM and extract nontraditional solutions, the government needs to use the FCCOM to assist, reimburse, and compensate the contractors' capital investment.

As the government uses significant, irresistible incentives to lead the industrial revolution in AM, the government can effectively reshape the defense industry landscape. The government can reduce its risk of a limited supplier base by having a second supplier, or multiple suppliers, for its system acquisition and service support, particularly in the low-volume, low-quantity defense articles. In short, the PBL guidebook laid the generic, strategic framework for contract support, and this project identified the actionable items for execution by evaluating the environment, requirement, and characteristics of AM. A properly structured PBL contract could help to alleviate the workload of the contracting officer by placing this requirement on the prime contractor, thus helping to improve competition and achieve cost savings. With an adequate, carefully designed, and innovative PBL approach, the government can encourage research and development AM while helping contractors to improve the quality, reliability, and performance of their products and services.

For the past eight years, there has been an increasing push towards government insourcing. Insourcing, indeed, is a way to mitigate risk and provide some assurances when the marketplace cannot satisfy government requirements. However, reliance solely on insourcing could hurt the defense industry by eliminating the need for some companies.

Finding 2 and Recommendations

PBL is more of a buzzword than an attainable goal if the steps identified in the PBL guidebook and requirements from customers are not achievable or attainable. PBL is also not a one-size-fits-all tool (ASD[L&MR], 2016). The same rule applies here: Insourcing is not the ultimate solution. As this project shows in its research of the obsolescence management case associated with the Parasense sensor, even with dedicated government teams for obsolescence management, engineering advisories for risk monitoring and mitigation, organic capabilities for repairing, and a procurement contract and commercial supplier in place, insourcing does not address all the challenges and complexity of supporting complex defense systems. Moreover, the government does have certain limitations and constraints for ensuring that parts meet specifications. Despite the fact that the DoD has engaged AM for more than 20 years, the government has been a little behind on establishing the qualification or certification process for the use of 3D-printed parts as critical items on weapon systems. In contrast, the qualification, certification, and standardization of AM parts to meet FAA requirements and fielding for commercial use came from GE, without the direction or requirement from any government entity. NAVAIR's recent effort to shorten the AM parts certification process to weeks or even days by developing industry standards for 3D-printed parts is probably the area in which the government can most effectively add value to its operation and make sure it has access to this required capability.

As a result, the government's main challenge is to find the right balance between its essential need for insourcing and the many benefits AM capabilities offer. To do so, the government needs to evaluate its capacities and mission profiles carefully. First and foremost, the government is not in the manufacturing business and should focus on the inherent government functions that cannot be contracted out. In the operation and support of defense weapon systems, many parts and services are considered to be mission critical; however, producing these parts and providing the maintenance and services for them are not inherently government functions. Secondly, parts and services can definitely lead to a life-or-death issue, especially on the battlefield or in contingency situations. However, it is more important that the government can manage and satisfy its requirements through the proper sourcing strategies and channels, instead of providing the services or materials in-house.

To be more specific, perhaps the government needs to find ways to manage the IP rights for the use of AM and provide the regulatory oversight on the standardization, qualification, and certification of AM parts. Instead of relying on contractors to tell the government what to buy, how to manage, and how much to pay, the government probably should focus on insourcing those inherent government functions and be able to coordinate its efforts in the use of AM. Precisely as the SECNAV stated in his memo to the CNO, CMC, and ASN(RD&A), the DoN needs to increase the development and integration of AM, as well as develop the ability to qualify and certify AM parts (SECNAV, 2015). Moreover, the second half of SECNAV's 2015 memo identified standardization of the digital AM framework, end process integration, establishment of the DoN advanced integrated digital manufacturing grid, and formalized access to AM education, training, and certifications for the DoN workforce as more important than organic capabilities. Through the evaluation of the arrangement among Airbus, SAP, and UPS, this research project showed that Airbus is more concerned with selecting the right data management firm, SAP, and capable AM manufacturer, UPS, to satisfy the requirements for meeting its operational and logistical support demands for Airbus's global network.

Finding 3 and Recommendations

AM can improve competition and lower the risks associated with a limited supplier base by adding a second competitor, lowering the nonrecurring costs, eliminating the need for an economy order quantity, and achieving cost savings. AM could allow rapid prototyping—with an OSA design, more small businesses can research, develop, and test their products as subcontractors and help to improve the DDG 1000's capabilities, reliabilities, and sustainability. Last but not least, the use of AM will allow easier incorporation of the open architecture idea to develop new systems while using interface management.

Southard's (2016) iPDA analysis showed that the little bits and pieces of a circuit card can significantly affect the DDG 1000's mission and the obsolescence management forecast is only as good as the current data provided by the marketplace and industry for the next five years. At the same time, the obsolescence case of the Parasense sensor showed that the government sometimes needs to forecast further out into the future, perhaps 25 years or more. In the event that AM becomes the predominant manufacturing process for many low-demand, low-volume parts, the government can take advantage of this revolutionary market dynamic with proper planning. By using a properly structured approach with PBL, OSA, and AM, the government can predict, anticipate, and manage the risks of limited key ship components.

For existing requirements, the government could look into existing AM efforts among government agencies and leverage the equipment on hand from the multitude of entities that have already embraced this technology, including the Department of Energy, NASA, the USS *Essex*, Marine Corps Air Station (MCAS) Cherry Point, and Walter Reed National Military Medical Center in Bethesda, MD (SECNAV, 2015). NUWC, or a designated team, could look into the organic AM capabilities and determine if the government can 3D-print some iPDA parts. Moreover, since GE is not only the maker of the LEAP engine for commercial aviation but also the manufacturer of the LM-2500 engine for the Navy's Arleigh Burke–class destroyers, Ticonderoga–class cruisers, and America–class amphibious ships, the government should investigate the capabilities that GE has for certain existing engines' parts support and system upgrades. Last but not least, the DDG 1000 program can bring the composite deckhouse back onto the negotiation table since 3D-printed composite materials were approved for structural components of commercial ships in 2014 (Job, 2015).

For future requirements, the government should incorporate and insist on the use of new technologies to produce obsolete and low-volume/demand requirements when negotiating PBL arrangements with contractors. Since BAE is currently the prime contractor for DDG 1000's combat system suite and is also aggressively pursuing AM capabilities, it is important to have a discussion on the use of AM for system acquisition and O&S planning. BAE is also more likely to become the PBL provider based on current trends and the defense industry environment the government is in; therefore, it is imperative for the government to understand and define its requirement to develop and negotiate the proper measurement metrics for program execution. For certain military requirements, such as the DDG 1000's propeller, the challenge is to meet those stringent standards under extreme conditions. For example, a 3D-printed propeller for a naval warship would need to pass the shock test and sustain a prolonged period of high-speed maneuvering. It will be worth the effort to investigate the EBAM metal 3D printer, located at Lockheed Martin's manufacturing facility, which is capable of metal-printing parts up to 19 feet long. The government should direct its effort towards AM and take advantage of the SECDEF's plan to spend $72 billion on R&D (Buren, 2016).

Similar to PBL and insourcing, AM is a revolutionary manufacturing process that has certain limitations with the current state of AM technologies. AM is also not a one-size-fits-all tool/solution and might not be cost effective for every application. For example, manufacturers will continue to use their existing facilities and resources to produce those high-volume and low-complexity parts until the costs of maintaining those resources are no longer economically sound. In short, AM or 3D printing by themselves may not be the solution for many existing and future requirements; however, when the government can combine them with PBL and an open system approach, the government can significantly lower a program's cost, performance, and schedule risks. It is predictable that the Navy, especially the DDG 1000 program office, can benefit from AM development immediately and in the near future.

Conclusions

The DDG 1000 program's re-baseline, budget cuts, technology maturity issues, cost increases, and other unknown risks could have led these three ships into a perfect storm and a much cloudier, muddier future. Additionally, most of the DDG 1000 suppliers are sole-source and therefore enjoy a certain monopoly of power in the marketplace. Even though DDG 1000's increased parts costs associated with a sole-source or limited sources environment is a valid concern, the fact that the mere existence of DDG 1000's suppliers can significantly affect the program's performance is the primary concern for long-term O&S planning. As this project shows, without an effective way to lower startup costs and extract ROI, the government will not obtain competition or maintain a healthy industry base. AM, a revolutionary manufacturing process, is the potential answer to these problems.

The DDG 1000's OSA and PBL, by design or by accident, have jointly crafted an environment for the introduction and implementation of AM. The DDG 1000 program does not have scale economies due to the number of ships; therefore, DDG 1000 needs to seriously consider AM as a means to satisfy its low-volume, infrequent-demand requirements, as well as to mitigate the risk of a limited supplier base. AM can help to improve material availability and alter the traditional obsolescence management approach that is more likely to result in lifetime buy decisions with possible limitations. With PBL, OSA, and AM, the program office can invite more interested parties to participate and thus mitigate the risk of losing existing contractors. Since many of the major AM developers—such as SAP, BAE, Lockheed Martin, and Raytheon—are also the primary service providers of the DoN, and since the Navy has similar or better resources for DDG 1000 to mirror the agreement that Airbus, SAP, and UPS developed, AM is a viable solution in mitigating the risks identified in this research.

AM will not replace conventional manufacturing methods for high-volume, low-complexity parts in the near term and foreseeable future; however, AM will continue to evolve as the process matures and will significantly alter make-or-buy decisions for low-volume, low-quantity items. DDG 1000, as the tech engine for the fleet, will reap the benefits of rapid prototyping, faster production, better quality parts, lower prices, and minimum risks that AM offers.

Summary

Looking forward, the advent of AM and associated future technology advancements will continue to reshape the industry landscape and challenge the business decision-making process. From the commercial marketplace to the private defense industry, AM is aggressively pursued and incorporated into business decisions. The challenge for the DoD acquisition community, across the spectrum from system engineering to contracting, is to incorporate AM in decision-making throughout all phases of the product life cycle. There are many uncharted areas for the use of AM developments to identify the capability gaps, to improve system readiness, and to meet future mission requirements; therefore, the DoD must lead from the forefront and take a holistic approach to integrating AM. Defense system acquisition, like the DDG 1000 program, can significantly benefit from the use of AM and drastically reduce the risks of limited key components.

References

Assistant Secretary of Defense for Logistics and Materiel Readiness (ASD[L&MR]). (2016). *PBL guidebook: A guide to developing performance-based arrangements.* Washington, DC: DoD.

Buren, A. (2016). *US Navy plans to fly a Boeing V-22 Osprey aircraft with 3D printed part in June*. Retrieved from http://www.3ders.org/articles/20160518-us-navy-announces-test-flight-with-a-boeing-v-22-with-3d-printed-part-in-june.html

Job, S. (2015). Composite hatch cover approved for use in commercial ship. *Reinforced Plastics, 59*(2), 58.

Secretary of the Navy (SECNAV). (2015, September 3). *Additive manufacturing/3-D printin*g [Memorandum]. Washington, DC: Author.

Southard, C. (2016). *DMSMS analysis of iPDA circuit card.* Keyport, WA: Navy Undersea Warfare Center (NUWC).

Acquisition Research Program
Graduate School of Business & Public Policy
Naval Postgraduate School
555 Dyer Road, Ingersoll Hall
Monterey, CA 93943

www.acquisitionresearch.net