3D Printing for Improved Maintenance and Sustainment of Shipyards – Phase II

Final Report

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Acronyms and Abbreviations

Term	Definition
3DPC	3D Printing Corporation, K. K.
AM	Additive Manufacturing
APAC	Asia-Pacific
ATDM	Accelerated Training in Defense Manufacturing
CAD	Computer-Assisted Drawing
CTMA	Commercial Technologies for Maintenance Activities
DED	Direct Energy Deposition
DOD	Department of Defense
MRO	Maintenance and Repair Organization
NCMS	National Center for Manufacturing Sciences
ODASD-MR	Office of the Deputy Assistant Secretary of Defense, Materiel Readiness
QA	Quality Assurance
QC	Quality Control
SRF	Yokosuka U.S. Naval Ship Repair Facility
SME	Subject Matter Expert
U.S.	United States

1. Executive Summary

The United States (U.S.) Department of Defense's (DOD) initiative to integrate advanced manufacturing technologies, such as Additive Manufacturing (AM), into the Asia-Pacific (APAC) and specifically Japan forward-deployed operations is a strategic move aimed at overcoming unique operational challenges while enhancing overall mission effectiveness. Most of the workforce in these operations consist of locally contracted foreign nationals, and the DOD relies heavily on local companies for essential repairs and services. This operational context presents distinct challenges but also opportunities for leveraging advanced manufacturing technologies.

This project represents a substantial advancement in leveraging AM for governmental uses, fueled by a combination of educational initiatives, hands-on demonstrations, and cooperative problem-solving. The 3D Printing Corporation, K.K. (3DPC), equipped with cutting-edge AM facilities and a team of expert engineers, granted the Yokosuka U.S. Naval Ship Repair Facility (SRF) unparalleled access to this transformative technology. Through a series of project collaborations, training workshops, and tailored tutoring sessions, the core staff of SRF's Innovation Lab acquired the necessary skills to showcase practical 3D printing applications. These efforts culminated in the creation of tools and everyday items that significantly improved operational efficiency and quality of work within the workshops.

The achievements to date set the stage for further exploration and integration of AM technologies, heralding a future of innovative, cost-efficient, and technically superior workflow solutions. The 3DPC team's proactive engagement and relationship building positioned them advantageously when an urgent need arose during a ship repair operation. Through productive dialogue, the team effectively clarified requirements and devised corresponding solutions. This success was facilitated by robust communication exchanges in both English and Japanese, catering to the diverse composition of SRF's engineering team, which includes both American and foreign nationals. Introducing new technology and design concepts necessitates more than simple translation; it demands a deep understanding of each party's perspective to identify and address underlying concerns and needs comprehensively. As the team continued their progress, the insights gained and the connections forged throughout this project will lay a strong foundation for navigating the challenges associated with AM adoption, fully harnessing its capabilities to meet the dynamic requirements of SRF.

Funding was secured for the collaborative initiative through the National Center for Manufacturing Sciences (NCMS) Commercial Technologies for Maintenance Activities (CTMA) Program and the Office of the Deputy Assistant Secretary of Defense, Materiel Readiness (ODASD-MR).

1.1 Results

This second phase of the project evolved in two parts. September through May, the Innovation Lab staff, supported by 3DPC, enhanced their design, fabrication, and post-processing skills. June through September, the ship repair engineering staff became engaged, and the team began exploring 3D printing of metal parts for ship repair.

September through May, the team was able to increase the design and fabrication of non-critical items at the SRF Innovation Lab. These non-critical items included decorative items such as a custom trophy, branding iron, and a plaque. The lab staff also produced useful items such as a helmet lamp mount, sheet metal edge protector, phone protective covers. These capabilities were developed through SRF staff participation in 3DPC-provided workshop courses delivered in October 2022 and May 2023. In addition, the 3DPC Senior Design Engineer provided individual training for Innovation Lab staff on working with Solidworks Computer-Assisted Drawing (CAD) and designing for specific projects of interest to SRF. As a result, SRF Innovation Lab staff was able to independently support their internal customers' request for plastic and composite 3D printed items. The Innovation Lab developed a sample library and displayed the items produced for visitors to see the potential for 3D fabrication. To enable continuous operation, Phase II included materials. SRF staff accessed local stock of filament for immediate delivery.

The second part, June through September 2023, was initiated unexpectedly during a visit by 3DPC engineers to the SRF Sasebo operations. The lead engineer at SRF Sasebo requested that 3DPC assess a replacement of a fire main pipe section using 3D printing. The purpose of the fire main pipe section is to reduce the pressure (decompression pipe) between the inlet and outlet of the section. The initial request was to duplicate the current design. However, since the design used items available through traditional manufacturing processes, the design was not suitable for 3D printing. Through development of digital designs and engineering simulations (digital), 3DPC demonstrated the feasibility of creating an organic 3D printed design. This was accomplished by using the original design to validate a fluid dynamics model which will enable correlation of the 3D printed design to the original performance.

The introduction of metal 3D printing highlighted the need to engage SRF's quality assurance (QA) and quality control (QC) staff. SRF's engineers have started to reach out to this group to engage with them.

1.2 Benefits

The main benefit of this project was to enable SRF to join the growing AM community within DOD by providing access, education, and experience with AM technology. This enables the bigger plans such as:

- **Increased readiness** through production of obsolete or long-lead items
- **Enhanced capabilities** through mission-tailorable solutions and employment of designs not otherwise possible
- **Maintain operational availability** through "good enough" production at the point-of need

Industry grows when new manufacturing processes are enabled. The available and growing digital inventory of AM parts provides new ways for industry to contribute to the supply chain and participate in local supply of necessary goods.

The strategic adoption of advanced manufacturing technologies in forward-deployed operations allows the DOD to address unique challenges head-on, enhancing operational readiness, empowering the local workforce, improving supply chain resilience, and achieving cost savings. This forward-thinking approach ensures that the DOD can maintain a competitive edge in rapidly evolving global scenarios.

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1.3 Recommendations

One of the most challenging points is that the 3D printed part is usually not the same as the original part it is replacing. Understanding the functional requirements and critical risks is vital to creating a useable 3D printed part. Generally, the part specifications do not contain this information. Much can be inferred from the materials and design, but values that can be used for verification require engineering input.

> *Recommendation:* Educate Innovation Lab staff, create procedures, and implement a process for capturing and approving functional requirements.

SRF's work environment is fast paced with the priority to keep the maintenance and repair organization (MRO) schedule. It has been difficult to experiment with alternative solutions because the organization has a requirement to follow established practices. Good potential use cases will not, at first attempt, provide a timely solution. However, working through the experimental process is critical to identify key process steps and methods to address specific requirements for implementing AM technology.

> *Recommendation:* It is vital to create trial use cases and follow through the workflow to establish a foundation for developing procedures.

Funding included investment of SRF's Innovation Lab personnel and equipment. However, the time and effort required by the end-use customer, such as one of the MRO shops, was not considered. These shops must charge their time to specific approved MRO activities. Any experimental work is not covered under existing procedures.

> *Recommendation:* Establish policies and procedures to enable resources to be assigned for experimental work.

QA/QC for AM is a critical need to enable acceptance of additively manufactured items. Naval Sea Systems Command is issuing technical publication guidelines. Until now the quality engineering staff has not engaged significantly with the activities. The ability to apply available equipment, techniques, and methods for verifying AM items has not been assessed.

> *Recommendation:* Assessment of current resources and capabilities to verify AM items. Determination if additional skills, methods, and equipment are required. Training of QA/QC staff.

1.4 Technology Transition

The training of subject matter experts (SMEs) and embedded AM technology at SRF's facility prepares SRF to assess opportunities and produce parts by AM. The U.S. Navy is acquiring metal AM technology, so the experience drawn from working with metal parts made by 3DPC will facilitate transitioning to in-house metal AM.

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1.5 Invention Disclosure

☐ Yes Inventions ☒ No Inventions

DD882 Invention Report sent to NCMS ☒

1.6 Project Partners

- U.S. Navy, Yokosuka U.S. Naval Ship Repair Facility (SRF)
- 3D Printing Corporation, K.K. Yokohama, Japan
- National Center for Manufacturing Sciences (NCMS)

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2. Introduction

2.1 Background

There are initiatives across the Navy to develop more local solutions to address availability of mission critical components and systems. The promise of AM to provide local capabilities has been identified as an important solution. The need for alternatives is especially critical in forward deployed locations such as Japan. The SRF base, as a large repair facility, has a full complement of shops to address ship maintenance and repair. Even with this capability, the base will rely on local solutions in the event of a crisis that disrupts the current supply chain.

This project was vital to SRF's operations to enhance responsiveness of local sourcing for critical items. Once developed, this capability provides an alternative option to SRF when accessing materials and supplies from outside Japan is not available. AM is a new fabrication process that can utilize digital storage and delivery of necessary items. The Navy and other DOD operations are rapidly growing the available digital library of parts that can be fabricated by 3D printing. For SRF to take advantage of this emerging resource, the infrastructure to certify and produce items using 3D printing must be established.

2.2 Purpose

This project created the Innovation Lab 3D printing center with access to metal, composite, and plastic fabrication technology. The lab served as an education and information hub to create awareness of this technology as well as provide hands-on training of SMEs. Through application projects, 3D printing was used to produce prototypes and end-use items. This was the second phase of a three-phase project at SRF.

2.3 Scope/Approach

The project was approached on three fronts: 1) create awareness within the shops, engineering, and management about 3D printing; 2) training of SMEs to understand the concept and applications for 3D printing; and 3) applying this knowledge to use cases.

The target solution was to utilize 3D printing to create items that could not be obtained in a timely manner from traditional sources. The most challenging application was any item for shipboard use since these items were typically high severity and performance requirements were not readily available due to their proprietary nature. However, the other opportunity was to create items such as shop tools and user access items (knobs, switches, levers, etc.) that, when not present, can also cause significant delays and performance degradation.

The deliverables for this effort included training workshops, engineering design and analysis for mutually agreed upon projects, and AM of parts in plastics and metals to demonstrate feasibility of new processes.

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3. Project Narrative

The start of Phase II was marked by a transition of SRF's leadership and changes in the Innovation Lab personnel. The SRF Senior Innovation Lab Engineer retired in July. His role of interfacing with the SRF shops as an experienced shop manager was not replaced with someone of similar experience. Furthermore, the new department head for Innovation and Continuous Improvement was heavily involved in other departmental priorities. The active SRF staff were Japanese nationals: the newly appointed Assistant Innovation Program Manager, and the Assistant Technology Insertion Manager. As a result, the focus shifted from engaging with potential projects for ship MRO or tooling to workplace improvement items for the shop staff and creative works such as trophies and plaques.

3.1 First Workshop

The first workshop was held in October 2022. The six participants (four engineers and two technicians/machinists) from Yokosuka and Sasebo completed the training in composite and metal AM. They also applied design thinking to an application project of their choosing. This group developed a hard-hat clip for securing a headlamp shown in Figure 1 and Figure 2.

Figure 1. Original Helmet Clip
Problem: Workers need to access tight spaces on the ship with poor lighting. Helmets are equipped with a strap-on headlamp that is kept in place by a clip. Sometimes they want to remove the light from the helmet to hold it by hand for better lighting position. The current clip requires user to remove their helmet in order to remove the headlamp. It is dangerous and not allowed to remove the helmet in these conditions.

Figure 2. New Clip Design Variations and Headlamp Mounting Adapter
Solution: The new clip has many advantages: snaps in place; can accommo–date a variety of band widths; is easy to secure and release the band; varies in the design to allow for adapting for other tools; and the digital design and 3D printing allows easy customization of the clip.

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3.2 Second Workshop

Starting in May 2023, SRF hosted a 3DPC training workshop in a weekly format, running one day each week until June, with six students participating. The curriculum covered basic 3D printing operations and strategies, enriched with design thinking and practical implementation. This cohort produced the highest number of ideas compared to previous workshops. By tackling real-world problems, they learned valuable skills in adapting designs and maximizing 3D printing's potential. A key focus was on broadening their problem-solving techniques, emphasizing the importance of moving beyond traditional methods to embrace the layered approach inherent in 3D printing (Figure 3 through Figure 10).

Figure 3. (Left) 3DPC Initial Brainstorming Ideas; (Right) 3DPC Sr. Design Engineer Explains Design Considerations and Strategies

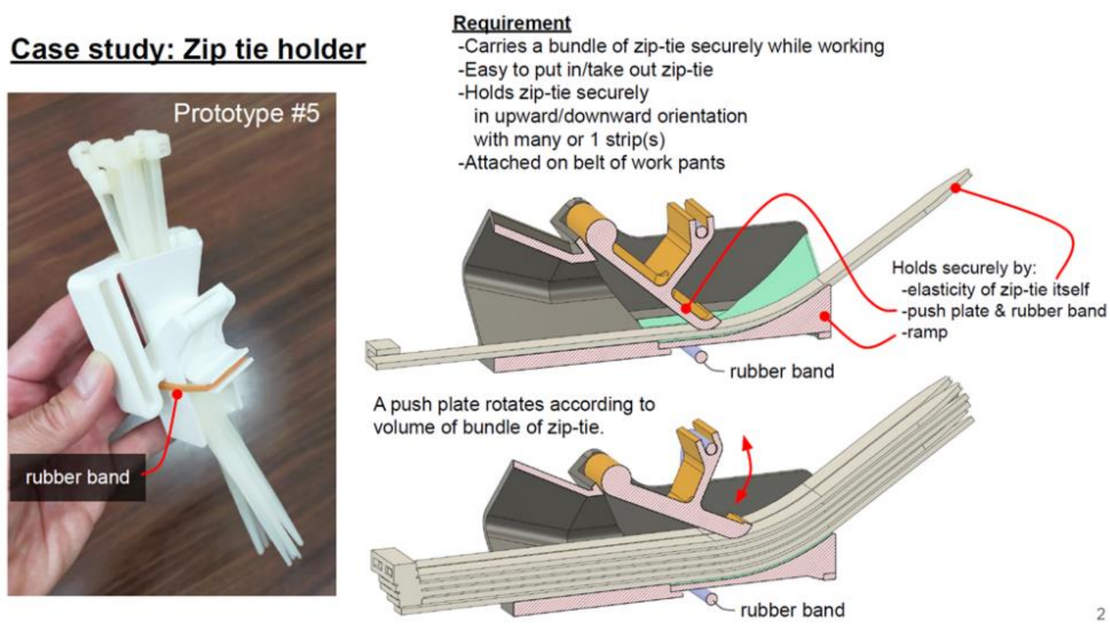

Figure 4. Case Study #1– Zip Tie Holder
The final product is shown here.

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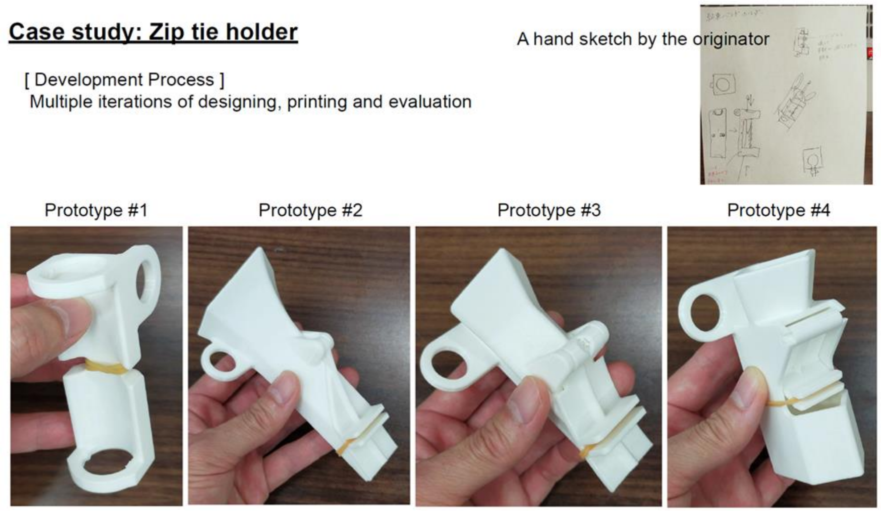

Figure 5. Case Study #1 – Development Process

Figure 6. Case Study #2 – Flashlight Holder with Magnet

Figure 7. Case Study #3 – Card Holder Hinge Replacement Part

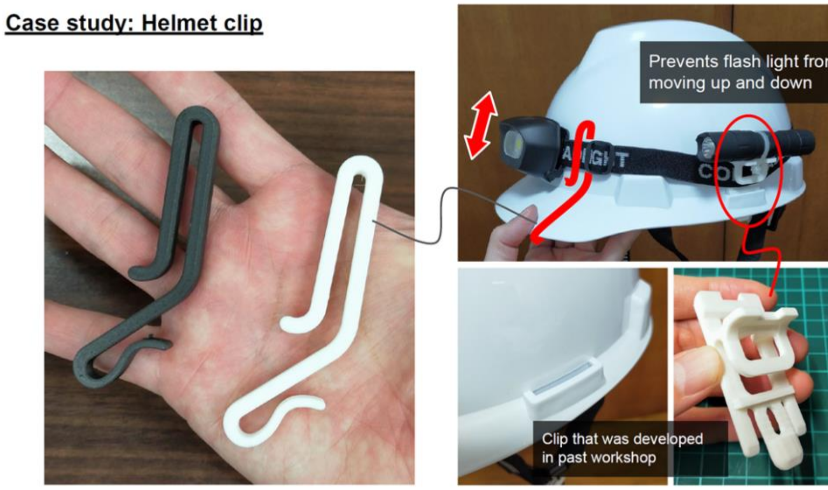

Figure 8. Case Study #4 – Helmet Clip

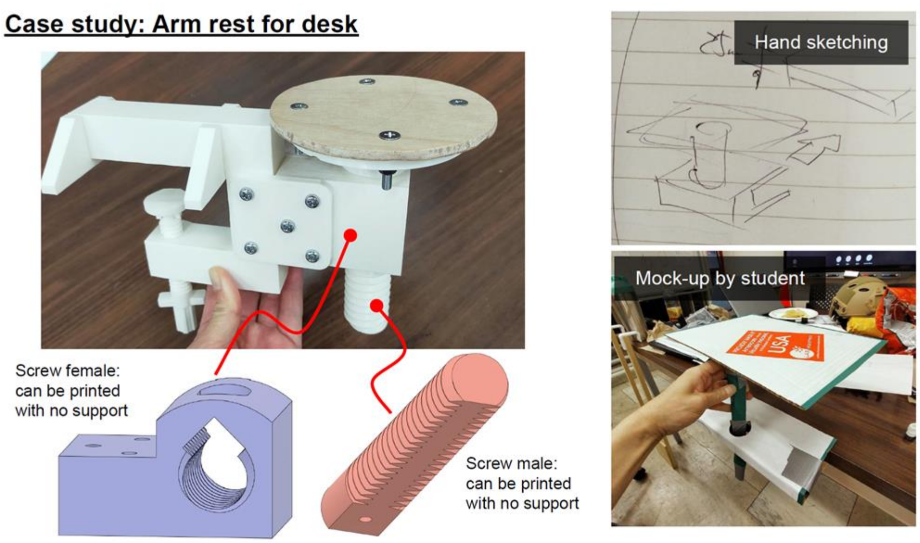

Figure 9. Case Study #5 – Arm Rest for Desk

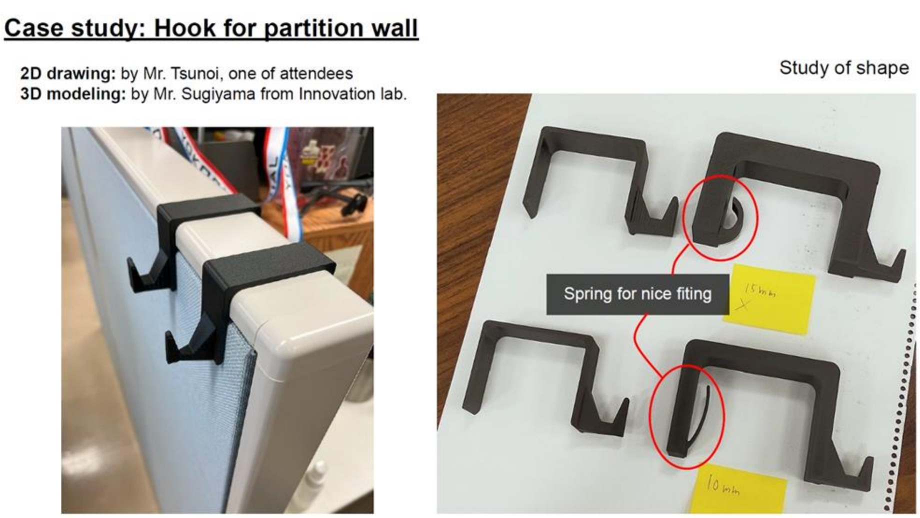

Figure 10. Case Study #6 – Hook for Wall Partition

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3.3 Innovation Lab Internal Customer Requests

The Innovation Lab staff worked on an internal request to print mobile phone protective covers, working with the Ultimaker printer, and promoting the 3D printing resources of the lab. The projects that had been initiated in Phase I such as the repositionable mounting bracket for pot puller, Shop 700 pulley concept, and diesel jig for Sasebo were discontinued due to lack of interest from the requesting department. During this time the Assistant Innovation Program Manager increased his CAD skills and ability to screen potential applications for 3D printing.

3.3.1 Edge Guard Concept

February and May 2023 were marked by increasing requests from various SRF shops to solve daily use issues with 3D printing. These requests included an edge guard to protect stocked sheet metal. The requestor came with initial concepts and 3DPC provided alternatives to reduce cost and improve 3D printability. Figure 11 shows the current edge projection solutions. Figure 12 and Figure 13 are two designs proposed by the inventor. 3DPC used the inventor's designs as a starting point and developed designs that reduced the amount of material (Figure 14 through Figure 18) and support. Support removal is one of the post-processing steps that can be very time consuming if considera-tions to minimize supports is not possible due to other design constraints. Table 1 summarizes the cost estimates for 3D printing the various designs.

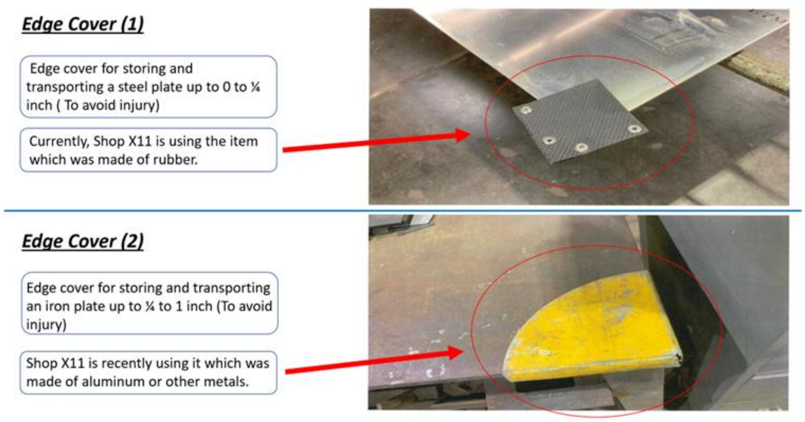

Figure 11. SRF Current Edge Protection Solution

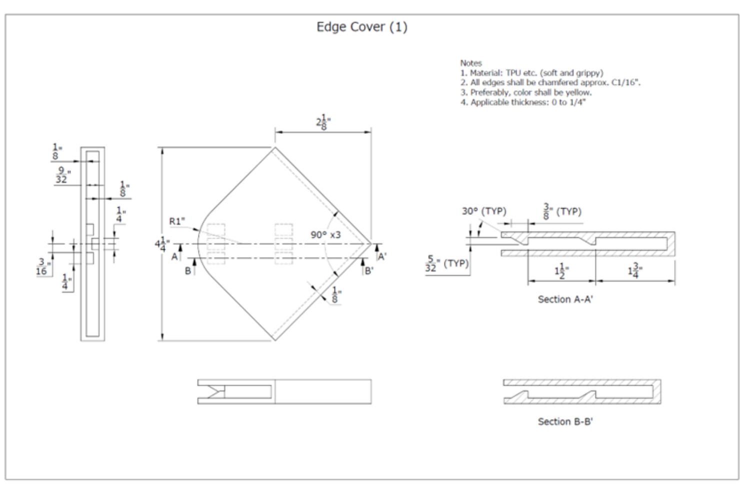

Figure 12. SRF Inventor's Original Design

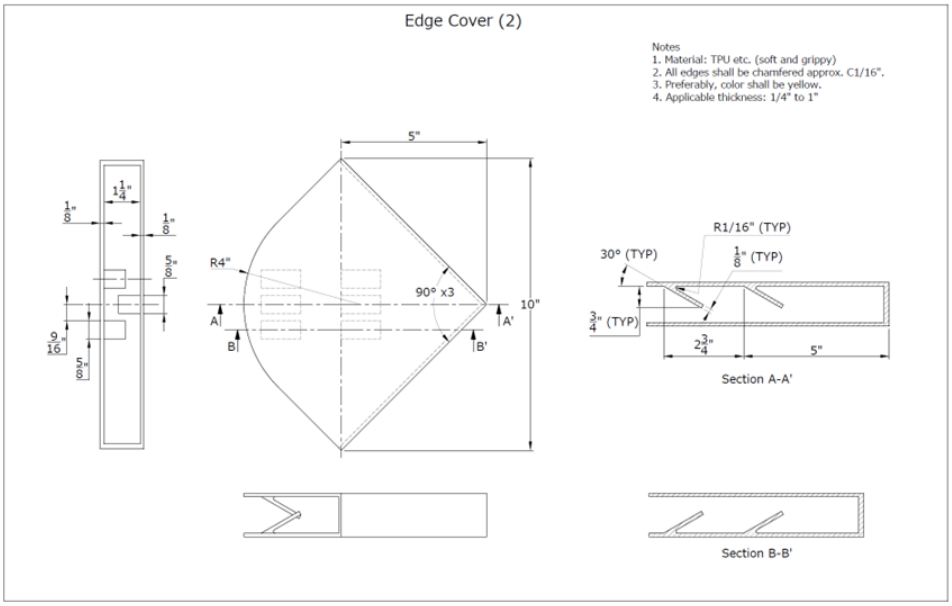

Figure 13. SRF Inventor's Alternate Design Version

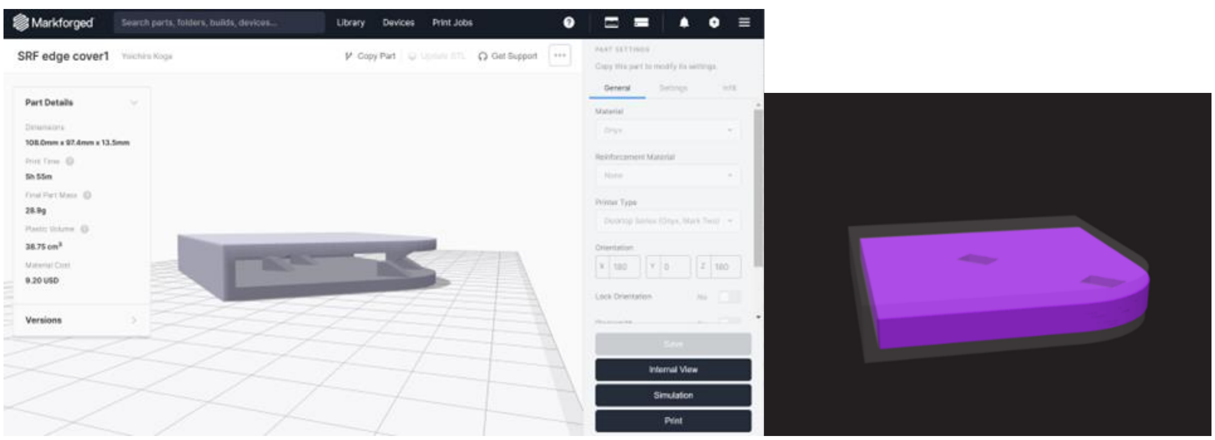

Figure 14. SRF Edge Cover 1 – Original 3D Print Build
Purple area is the support material.

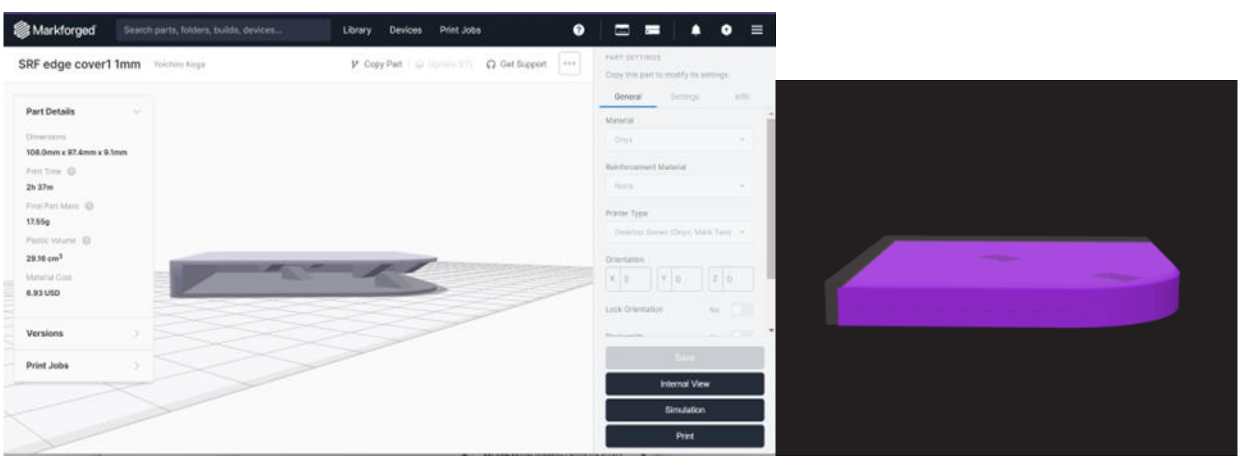

Figure 15. SRF Edge Cover 1 – Reduced Wall Thickness
Purple area is the support material.

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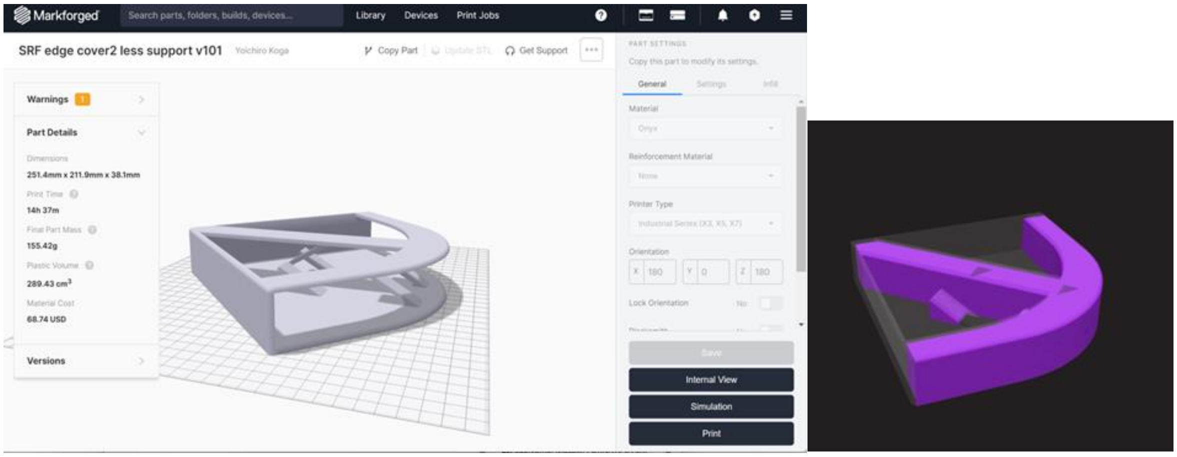

Figure 16. SRF Edge Cover 2 – Less Support
Purple area is the support material.

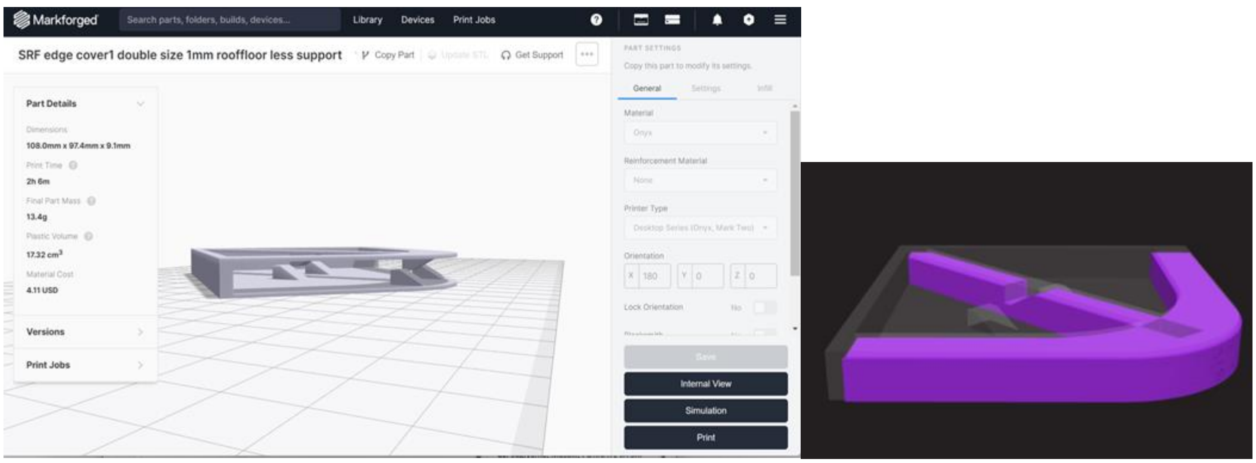

Figure 17. SRF Edge Cover 1 – Less Support, Reduced Wall Thickness

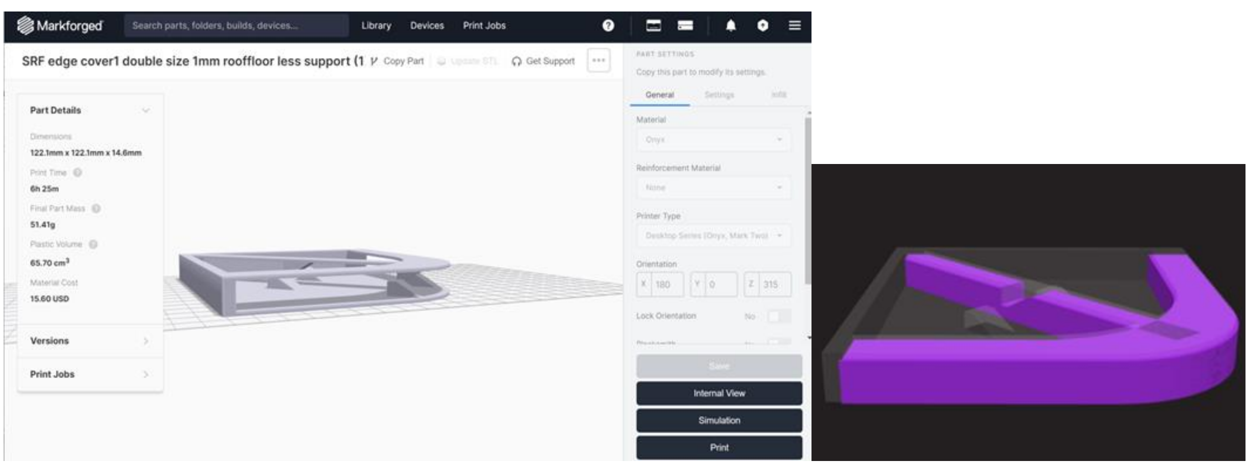

Figure 18. SRF Edge Cover 1 – Large Size, Less Support, Reduced Wall Thickness

Table 1. 3D Printing Cost for Design Alternatives for Edge Guard

Edge Guard									
Description	Size (mm)			Time			Material Cost ($)	Post Processing* ($)	Total Price ($)
	L	W	H	h	m	hour	USD	USD	USD
Cover 1 – Original (Fig 14)	108	97	13.5	5	55	5.92	9.20	6.00	61.62
Cover 1 – Reduced wall (Fig 15)	108	97	9.1	2	37	2.62	6.93	6.00	33.46
Cover 2 – Less support (Fig 16)	251	211	38	14	37	14.62	68.74	15.00	198.42
Cover 2 – Less support Scaled	113	95	17	5	32	5.5	6.82	15.00	65.00
Cover 1 – Less support (Fig 17)	108	97	9.1	2	6	2.10	4.11	3.00	23.59
Cover 1 – Large less support (Fig 18)	122	122	15	6	25	6.42	15.60	3.00	68.95

** Including machine time at $7.85/hour and post processing technician time ($60/hr.)*

The Cover 2 design was not practical for 3D printing because the feather-like protrusions required support and support removal. It required support removal that could damage the final product because the feather-protrusions were quite thin. One alternative could be to leave the support in the feather area, thus reducing the post-processing work and still providing a relatively collapsable protrusion. The most cost effective design was the Cover 1 with less support (Figure 17). This type of product was a good use case for 3D printing because the shop requested the edge guard be produced to meet a range of sheet thicknesses from 0 to 1 inch. Additional sizes can be created by adjusting the scaling of the item in the build software, so no additional CAD work is necessary.

3.3.2 SRF Plaque

A plaque for SRF was requested. The original version of the plaque was made by casting metal and then painting by a skilled artisan to match the colors in the image of the SRF logo (Figure 19). A 3D printed version was created by printing each colored section separately. It was not possible to exactly match the SRF image colors, but similar colors were used to facilitate identification for the painting process. Since the components were separated by color, the painting process did not require a highly skilled artisan. The components were assembled after painting.

Figure 19. SRF Plaque
(Left to Right) 3D printed version, original metal cast plaque, image used as a model for the design.

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3.3.3 Safety Man Trophy

Figure 20 shows a project that was designed by the local base high school students. It is an award for commendable safety performance. The prototype shown in Figure 20 was printed using Fused Filament Fabrication (plastic extrusion 3D printing). 3DPC was consulted to provide pricing for producing a more high-quality product using metal plating of the helmet and smoother body fabrication. After consideration, SRF decided to produce the trophies themselves to save costs.

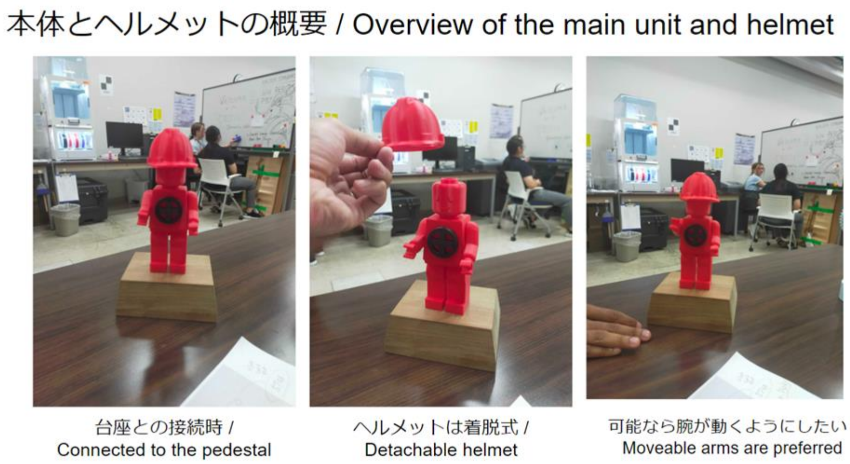

Figure 20. Safety Man Basic Design

3.3.4 Innovation Lab Independent Developments

As a result of the Innovation Lab Assistant Manager’s increased knowledge and skills, he has been able to recruit and create solutions for several shops at SRF. Without 3DPC support, he was able to successfully create many solutions for the shop and base staff. These items are shown in Figure 21 through Figure 27:

Figure 21. Telescopic Inspection Mirror Protective Case

Figure 22. Bullet Case
Request: increase case capacity from 50 to 51 to accommodate 3 full mag–azine rounds and replace the easily damaged polystyrene to make it more robust. Solution: Capacity 51 bullets and printed in plastic.

Figure 23. (Left) Welding Handset with Pen Mount for Practicing Welding Techniques; (Right) Faro 3D Scanner Replica End Arm Effector

Figure 24. Pipe Welding Patterns

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Figure 25. Security Box for Numeric Keypad
Replaced makeshift cardboard box.

Figure 26. Custom Valve Knob
Replaced the easily broken original plastic version with a carbon fiber reinforced plastic.

Figure 27. Custom Mandrel Tool
Improved performance and consolidated two tools into one.

3.4 Shipboard Case

In June, the 3DPC team visited SRF's satellite facility to reconnect with a former student and introduce the latest in 3D printing. During their visit, the lead engineer sought the 3DPC team's expertise for a maintenance challenge involving a non-critical metal fire main decompression pipe, which could not be replaced due to unavailability of the original part or materials. This situation highlighted the potential for metal 3D printing as a solution. The engagement fostered a collaborative relationship with SRF's Japanese and American staff, offering insights into the decision-making process for approving non-standard parts. The 3DPC engineering team embarked on a review and planning phase for the decompression pipe MRO project, marking a pioneering innovation in using metal 3D printed parts for shipboard items (Figure 28). The project's lead SRF engineer was open to collaborating on the approval process for the 3D printed part.

Activities of the 3DPC engineering team involved design assessment, flow and pressure drop modelling, test unit preparation for Meltio Direct Energy Deposition (DED) printing parameters, and exploring alternative manufacturing methods (Figure 29). The pressure drop modelling resulted in generating data aligned with the original design intent. Since the model performance could be confirmed, this model could be used to evaluate the performance of new designs.

The data and tests from 3DPC demonstrated that replicating the original design was unsuitable for AM. Participants recognized the opportunity to create a unified design, as AM enables the in-situ fabrication of internal structures. Originally, the design consisted of perforated sheet metal spaced apart by spacers, with the assembly of these plates into the holding tube being both time-consuming and labor-intensive. Moreover, repairing a corroded assembly is impractical due to the tight fit of the plates within the outer tube.

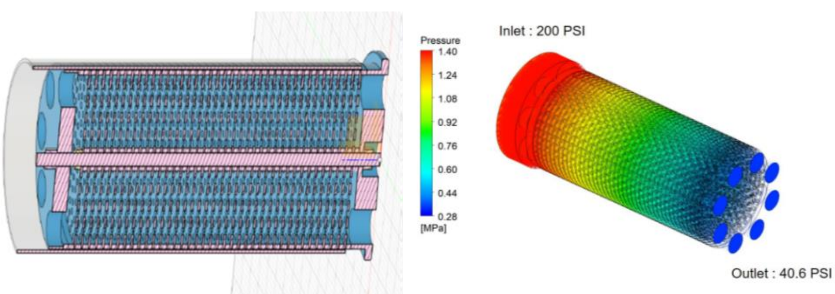

Figure 28. (Left) Decompression Pipe CAD Model; (Right) Computational Fluid Dynamics Model

Figure 29. Meltio DED Pipe Test Unit Samples – Material SUS308L

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4. Conclusions

The project achieved notable breakthroughs, underpinned by innovative applications of AM that have substantially improved workflow efficiencies in SRF's operations. Key to this success was the pivotal role of the Innovation Lab's Associate Manager, whose expertise in CAD and strong rapport with shop staff catalyzed a transformative adoption of AM technologies. As mentioned in the Project Narrative, the Innovation Lab's Associate Manager's CAD skills and AM knowledge enabled such items as the Faro arm replica (Figure 23), bullet case (Figure 22), and pipe weld sizing tools (Figure 24). By creating useful examples of the possible, the other shop staff members are increasingly approaching the Innovation Lab's Associate Manager to explore workflow solutions. Furthermore, the workshops led by 3DPC were instrumental in demonstrating the value of AM by engaging shop staff to experience the opportunities AM provides to create solutions that would have previously been cost prohibitive or technically challenging. These initiatives not only showcased the potential of AM to address complex challenges but also inspired a culture of innovation among the shop staff, leading to a proactive exploration of AM-based workflow solutions.

A second major achievement was the initiation of a collaborative dialogue with SRF's engineering team regarding the application of metal AM for shipboard components. This interaction laid bare the challenges inherent in adopting metal AM, including regulatory, technical, and quality assurance hurdles. Despite these challenges, the engagement sparked a comprehensive review of potential applications for AM, highlighting its benefits and limitations. Moreover, it fostered a keen interest among the engineers to delve deeper into the metal AM process, recognizing the unique considerations required for the final product's bulk material. This enthusiasm has translated into increased participation in discussions and educational visits to 3DPC facilities, signaling a growing commitment to integrating AM technologies into future projects.

In conclusion, the project has marked a significant stride forward in harnessing AM for governmental applications, driven by educational outreach, practical demonstrations, and collaborative problem-solving. The successes achieved pave the way for further exploration and adoption of AM technologies, promising to revolutionize workflow solutions with innovative, cost-effective, and technically advanced alternatives. As we move forward, the lessons learned, and relationships built during this project will serve as a foundation for overcoming the challenges of AM adoption and leveraging its full potential to meet the evolving needs of SRF.

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5. Project Benefits

5.1 Benefits for the General Public

The initiative to augment the agility and efficiency of the supply chain through the promotion of alternative advanced manufacturing methods, notably AM, brings substantial benefits to the general public. The strategic shift towards innovative manufacturing techniques has catalyzed a ripple effect, fostering investment and interest in advanced manufacturing within the local industry. The following sections outline the key benefits of this project to the general public:

Economic Growth and Industry Investment: Local industries are encouraged to invest in new technologies to meet the growing demand for advanced manufacturing capabilities. This investment is not confined to the procurement of state-of-the-art machinery and equipment but extends to the development of infrastructure and the creation of high-value jobs within the manufacturing sector. As industries adapt to these new manufacturing paradigms, we are witnessing a revitalization of the manufacturing landscape, contributing to economic growth and enhancing the nation's competitive edge in the global market.

Workforce Development and Job Creation: One of the most direct benefits to the general public from this project is the emphasis on workforce development, exemplified by initiatives such as the Accelerated Training in Defense Manufacturing (ATDM) program in Danville, VA. ATDM and similar programs are designed to equip individuals with the skills and knowledge required to excel in advanced manufacturing roles, particularly in sectors critical to national defense. These training programs not only provide participants with valuable employment opportunities but also ensure that the workforce is prepared to meet the future needs of both defense and civilian manufacturing industries.

Enhanced Supply Chain Resilience: The adoption of AM technologies has implications for supply chain resilience. By fostering a more agile and adaptable manufacturing ecosystem, these technologies can reduce lead times, minimize dependence on complex global supply chains, and enable more efficient response to market changes and emergencies. For the general public, this means greater stability in the availability of goods, potentially lower costs, and enhanced national self-reliance in critical manufacturing capabilities.

Innovation and Technological Advancement: The project's focus on alternative advanced manufacturing techniques, particularly AM, serves as a catalyst for innovation and technological advancement. As local industries and educational institutions rally, we are likely to see an acceleration in the development of new materials, processes, and applications for AM. These advancements have the potential to lead to new products and services that can improve quality of life, environmental sustainability, and healthcare outcomes for the general public.

In conclusion, initiatives to enhance supply chain agility through AM have far-reaching benefits for the general public, spanning economic growth, workforce development, supply chain resilience, and technological innovation. By fostering a robust ecosystem for advanced manufacturing the groundwork is laid for a more prosperous, resilient, and technologically advanced society.

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5.2 Benefits for DOD

The DOD's initiative to integrate advanced manufacturing technologies, such as AM, into the APAC and specifically Japan forward-deployed operations is a strategic move aimed at overcoming unique operational challenges while enhancing overall mission effectiveness. The majority of the workforce in these operations consists of locally contracted foreign nationals, and the DOD heavily relies on local companies for essential repairs and services. This operational context presents distinct challenges but also opportunities for leveraging advanced manufacturing technologies. Key benefits include:

Enhanced Operational Capability: Implementing advanced manufacturing technologies enables the DOD to rapidly produce parts and equipment on-site or nearby, significantly improving operational readiness and reducing downtime for essential machinery. This capability is crucial in forward-deployed environments where traditional supply chains are stretched or disrupted.

Local Workforce Empowerment: By evaluating and adapting these technologies for use by locally contracted personnel and companies, the DOD can empower the local workforce, building capacity and fostering stronger partnerships. This is critical because the Japanese workforce and industry significantly lags the U.S. in adoption of AM. This approach not only supports mission objectives but also contributes to local economic development.

In conclusion, the strategic adoption of advanced manufacturing technologies in forward-deployed operations allows the DOD to address unique challenges head-on, enhancing operational readiness, empowering the local workforce, improving supply chain resilience, and achieving cost savings. This forward-thinking approach ensures that the DOD can maintain a competitive edge in rapidly evolving global scenarios.

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