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CAD Interoperability for Navy Reuse in Additive Manufacturing (AM), 3D Printing, Maintenance and Training

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Naval Postgraduate School / MOVES Institute

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CAD Interoperability for Navy Reuse in Additive Manufacturing (AM), 3D Printing, Maintenance and Training

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EXECUTIVE SUMMARY

Project Summary

Additive Manufacturing (AM) technology has a potential to affect and change everything in all services: logistics, repair, warfighting along with training, simulation, education and support. Additive Manufacturing (AM), 3D printing and CAD export are also critical for Navy maintenance. Rapid change continues to occur across the design, engineering, manufacturing, and production process - many products can now be fabricated using AM methods. Iterative design processes require close collaboration of all entities involved from design to production; with AM, the lines between these previously stovepipe steps become blurred. A need to design, test and adopt different maintenance workflow becomes a necessity in cases of preventive and corrective maintenance of mechanical components on Navy ships and aircrafts where such operations have major impact on operational readiness. This project proposed to study and test elements that were identified as critical for effective deployment of AM in Navy operations, with specific emphasis on maintenance operations, while remaining sensitive to other Navy domains and activities where the use of AM could bring significant value. Our overarching goal was to provide a comprehensive approach that would lead towards reduction of energy costs, as well as reduction of materials and human resources engaged in that process.

Keywords: *shipboard maintenance operations, 3D printing, 3D scanning, virtual training, energy savings, stereoscopic display, X3D*

Background

Additive Manufacturing (AM) technology has a potential to affect and change everything in all services: logistics, repair, warfighting along with training, simulation, education and support. The landscape of technology innovations is moving so fast that the opportunities to capture full potential for game-changing capabilities may easily get lost. With the emergence of low cost commercial-off-the-shelf solutions and high power computing, the current military acquisition system and infrastructure needed for rapid setup and large-scale adoption of new technologies, may not be best suited for more recent waves of digital innovations. The example domain that has been addressed in this project includes preventive and corrective maintenance of mechanical components

on Navy resources like ships and aircrafts – this domain can have major impacts on operational readiness. Corrective maintenance itself is characterized by an added level of complexity: given the nature of physical resources used in Navy domain that is reflected in the age and uniqueness of many components currently in use on the ships, the availability of needed parts and components further reduces the service flexibility. The characteristics and constraints of this domain space served as the ultimate motivation for our research efforts; our overall project objective is to provide a comprehensive approach that would lead towards reduction of energy costs, as well as reduction of materials and human resources engaged in that process. The objectives of this type are at the center of attention of the project topic sponsor OPNAV, N41.

The main objective for the part of the project that is focused on adoption of novel technologies, in our case Additive Manufacturing, is in acquiring more detailed understanding about the current practices, processes, global domain conditions, the existence of elements of supportive environment (physical infrastructure, expertise), current and projected promotion efforts and communication, user attitudes and parameters that can positively or adversely influence adoption of this technology in the Navy and military domain in general. The characteristics of the innovation and benefits it brings to its users are important elements that influence adoption of that innovation among its intended users [Rogers-1995]. Additional elements that significantly impact the rate of adoption are user-perceived usefulness of innovation, its ease of use and final user acceptance - these type of characteristics were studied and incorporated in Technology Acceptance Model (TAM) introduced and expanded in Davis (1986), Davis (1989), and Davis (1993), as well as by Venkatesh et al. (2000). A new theory - Unified Theory of Acceptance and Use of Technology or UTAUT also incorporate this type of considerations by Venkatesh et al. (2003). Discussions that we had with multiple institutions and individuals engaged in AM domain, generated a great interest for issues directly related to Protection of Intellectual Property Rights (IPR) associated with 3D models generated and maintained in support of AM activities. The issues in this domain have been addressed by several technical research teams for quite some time, especially the techniques commonly called 3D Watermarking in Ohbuchi et al. (1998), Praun et al. (1999), Benedens (1999), Harte and Bors (2002), Macq et al. (2015). However, the policies that would address this space are yet to be fully formulated.

Findings and Conclusions

Two domains with multiple issues were addressed in this work on additive manufacturing (AM): technology adoption studies and 3D model interoperability. Technology adoption study efforts included a master's thesis on large-scale adoption of AM in expeditionary missions by Friedell (2016), which included a formal study of the AM domain for naval use. Additional research explored effective use of stereoscopic displays for training on corrective and preventative equipment maintenance, producing a novel commercial-off-the-shelf (COTS) hardware/software solution for conducting and evaluating virtual assembly tasks.

3D model interoperability activities were focused around the Extensible 3D (X3D) Graphics International Standard (Brutzman and Daly (2007)). Lengthy ascertainment in concert with partners in the Web3D Consortium determined that common technical characteristics are found between Computer Aided Design (CAD) models, 3D printing, and 3D scanning. A shared strategy is now being pursued for addition of CAD-model export conversion, compatibly combined encryption/authentication/compression. These conclusions and activities were further verified by emergent work by ISO Joint Technical Committee (JTC-1) on 3D Printing and 3D Scanning across 20 different international standards. Additional synergies have emerged that demonstrate direct usefulness to model exchange between Navy and Marine Corps stakeholders. The SPIDERS3D program for Web-based visualization of ships, ports and piers uses database-driven models using compatible X3D models. Interestingly these same characteristics are shared with 3D-printable medical models found on the National Institutes of Health (NIH) Model Exchange.

As part of our work with the topic sponsor, groups and individuals who have been actively working in this domain, an information meeting titled "Naval Web-Based Collaboration and Model Exchanges using X3D" has been organized in February 2017. This meeting gave opportunity to review our work with the sponsor and discuss future agenda and collaborations with colleagues. NPS Am Wiki is an additional resource that has been created to house a diverse set of materials, data and documents created by NPS faculty and students who have been working on AM related topics, and to instigate collaboration with other colleagues (note: wiki page is publicly visible).

These results have the potential for broad impacts across the naval enterprise, both deployed and ashore. Allowing operators to view printed objects, collaboratively work over the Web and print/scan/modify 3D models brings multiple benefits to long-

standing logistics challenges such as diagnosis of materiel failures and confirmation of part correctness. A partnered approach between user-centered requirements and technical capabilities has been fundamentally productive. Project results show the potential for improved processes and capabilities across the Navy and Marine Corps.

Recommendations for Future Research

The nature of technology adoption process dictates that it has to be studied over longer period of time. It is recommended that the future studies in this domain acknowledge service needs as they are identified in this domain, and focus on likely conduits of adoption of AM system and technologies.

Viewability, interoperability, sharing and collaboration are driving forces for applying technical capabilities. Data-centric approaches for metadata information along with data authentication, compression and encryption can augment contracted products to protect the government's intellectual investments and paid-for assets.

In the naval domain, for both Navy and USMC, Fabrication Laboratories (FABLABs) are now becoming our partners of choice for exploring the role of technology and innovation catalysts that Additive Manufacturing (AM) brings. NPS faculty and students will continue to work on these worthy challenges for the broader benefit that occurs.

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